RECLAMATION OF OVERFLOWED LANDS

BY

ALBERT STEVENS FRY

B. S. University of Illinois, 1913

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

CIVIL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1918.

RECLAMATION OF OVERFLOWED LANDS

BY

ALBERT STEVENS FRY

B. S. University of Illinois, 1913

THESIS

Submitted in Partial Fulfillment of the Requirements for the

Degree of

CIVIL ENGINEER

IN

THE GRADUATE SCHOOL

OF THE

UNIVERSITY OF ILLINOIS

1918.

UNIVERSITY OF ILLINOIS

THE GRADUATE SCHOOL

April 16, 1918. 191__

I HEREBY RECOMMEND THAT THE THESIS PREPARED BY

ALBERT S. FRY

ENTITLED RECLAMATION OF OVERFLOWED LANDS

BE ACCEPTED AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE

PROFESSIONAL DEGREE OF CIVIL ENGINEER

F. H. Newell

Head of Department of Civil Engineering

Recommendation concurred in:

F. H. Newell
A. N. Talbot
A. P. Carman

Committee

RECLAMATION

OF

OVERFLOWED LANDS

TABLE OF CONTENTS

RECLAMATION OF OVERFLOWED LANDS

1. INTRODUCTION

Importance of Land Reclamation.- When the early settlers of the various parts of the United States selected the lands which they desired to cultivate, naturally they chose those that were best protected from damages either resulting from overflow waters or from a lack of water. The latter condition prevailed largely in the west and southwest and was general over a large area of land. To remedy the deficiency in water, the United States and large private companies have spent a great amount of money in constructing irrigation canals and structures. The other condition of too much water must be cared for by drainage of the wet and overflowed lands and it is concerning the steps to be followed in working out the reclamation of these lands that this thesis will be writen.

An idea of the import of reclaiming the waste lands may be gained when it is realized that, notwithstanding the progress that has been made towards drainage, there are probably over 100,000,000 acres, which is equal to over 150,000 square miles, still in swamps and wet lands in the United States. This vast area is almost three fourths as large as all of Germany and is about two and a half times as large as all of our New England States. A large part of the unreclaimed territiory lies in the

Mississippi River valley from a point near Cairo, Illinois south to New Orleans and extending between the hills that lie along the borders of the valley. Many large drainage projects have been undertaken in this section and many more are now under progress.

Factors in the Process of Reclamation.- The history and development of a drainage project groups itself into seven separate and distinct parts. First, in the inception of a drainage movement, before any success can be hoped for, it must be clear to all who are disposed to consider the matter rationally, that the carrying out of a reclamation plan must assure definite returns from a financial standpoint. When this fact is established, the legal organization of the project in accordance with the laws of the particular state must be promulgated. The next step is to provide for an adequate, safe, and economical plan for construction, the development of which requires the employing of competent engineers who are versed in a knowledge of the principles of drainage engineering. After the plans are made and the cost estimated, the costs must be assessed against the lands. These costs must be collected from the landowners in order to make payment for the construction of the improvements and this requires that the district first issue bonds to lighten the burden to the landowner of paying for the work. The improvements planned by the engineers must be constructed and the method of construction is closely allied with the equipment with which the work may be done. Finally, after the improvements have been constructed, they must be kept in good condition and maintained so that the desired results will be secured.

The seven steps in the history of a drainage development project will be treated in this thesis. The major part of the thesis, however, will be given over to a study of excavating equipment. This is not because that part of the subject is of greater importance than other parts but largely because that portion of the work was attacked first and because it offered such a wide field to cover. In order, however, to give an idea of the general steps governing the destiny of drainage projects, the steps in the program, aside from excavating equipment, are treated as fully as the time allowed for the writing of the thesis permitted.

2.

ECONOMICS OF DRAINAGE

Increase in Land Value.- Drainage gives a greater increased value to land than any other feature entering into its development. It is the magic wand that changes the almost valueless swamps to rich agricultural regions. That drainage is a sound economic proposition which will yield not only good but in most cases extraordinary returns may be evidenced by a consideration of the increased value of drained lands over the same lands in their swampy state.

In the Southern states, much of the land contained valuable timber. When this is once cut off the land becomes what is known as cut-over lands, that is lands containing no merchantable timber but full of scrubby worthless timber and innumerable stumps. In this condition, the high value which the land may once have had because of the timber it contained has been shorn from it and it is valued at from $5 to $15 per acre . Where such land is cleared before drainage takes place, it is worth from $30 to $45 per acre.

To install drainage systems to accomplish reclamation, will cost,on the average, something less than $10 an acre. There will be variations from this amount due to special conditions but for a general discussion of the economic benefit from drainage, $10 an acre may well be used.

If the land is originally worth only say $15 per acre and $10 is spent for drainage without otherwise improving the land the land value increases on the market not to the sum of the original cost plus the cost of drainage, but to a figure well in excess of that amount. This amount varies according to location and other conditions but usually is from $50 to $75 an acre. Cleared lands increase in value proportionally to from $75 to over $100 per acre. These figures apply immediately after draining, for the lands ordinarily continue to increase in value as the fields are cleared and cultivated and other improvements are added. Some lands that were almost unmarketable a few years ago are now selling at from $150 to over $200 per acre and are bringing rents as high as $20 an acre. These increases have been due to the construction of a drainage system which cost the owner less than $10 an acre.

Increase in Crop Value.- Drained lands will produce better and larger crops than undrained lands. The reasons for this are several The soil warms up earlier in the spring and on that account, more nitrogen is formed to nourish the plants. Seeds germinate earlier in well drained soils and fewer seeds will fail to germinate and come up. This insures a better stand of a crop and reduces the possibility of replanting. In the cotton states, the cotton crop is annually damaged greatly by the boll weevil. If the crop receives an early start, it will be so far advanced by the time that the boll weevil makes his appearance that the weevil can harm it but little. Drainage of the land has been found by the planters to be the best means of obtaining an early start on the weevil.

3.

LEGAL ORGANIZATION AND LAWS

Legal Processes.- It is of the utmost importance that the legal steps involved in the organization and management of the affairs of a drainage district or project shall be taken in compliance with the terms of the laws under which the district is organized. To this end, a thoroughly capable lawyer versed in drainage law procedure is invaluable in the furtherance of the interests of the district. If the correct legal steps are not taken, then the district will be unable to dispose of its bonds at the proper time and it may be necessary to retrace the various proceedings of a district if at some later time a flaw is found in an earlier proceeding. For example, if the proper advertising of a hearing on an original petition for the district is not carried out as the law requires, then it will be necessary to validate the district, to go thru the entire proceedings of filing petitions, holding hearings, making reports, and doing numerous other things that were all performed correctly themselves at one time but which were rendered valueless by the discovery of the fact that the district was not properly advertised at the beginning. This is but one example of the complications that do arise because the legal proceedings have not been carefully carried out. It is evident, then, that it is profitable to secure a competent attorney in whom dependence can be placed to follow out the requirements of the drainage law.

Drainage Laws and Court Decisions.- Each state has a drainage law of its own and procedure differs greatly under the different state laws. The courts have also rendered a large number of important decisions, some of which interpret the law for general drainage conditions which are likely to be met with in any state.

Altho the workings of the law really belong to the attorneys for a drainage district, the engineer should be thoroly conversant and familiar with the operation of any law under which he may be called upon to work. He will not only find this necessary and useful in performing the engineering work, but it is also important for his own protection in securing payment for his services. For example, an error in a boundary description advertising a hearing on a drainage district,in one case caused the court to decide that the description was invalid because it failed to describe anything and the engineers lost several thousand dollars which had been spent in making surveys and plans. The description was the work of the attorney and had not been checked by the engineers.

A study of the drainage laws of several states where drainage is a matter of importance together with a discussion of a number of the most important court decisions relating to drainage would be of interest but it is beyond the scope of this thesis to take up this study and discussion.

4.

ENGINEERING

Preliminary Investigations.- The drainage engineer is usually called upon to make a preliminary examination of a proposed drainage area and determine whether or not drainage is feasible and whether or not it will be profitable to spend money to reclaim the territory. In so doing, the engineer should make a personal reconnaissance tour of the area to be drained noting the particular features that would effect the drainage situation. All existing maps of the territory should be obtained, as quite often, information that is valuable in working out drainage has been collected for other purposes. The main problem to determine is that of an outlet for a drainage system. If it can be ascertained that a good outlet can be secured without too great expense, then the feasibility of draining the lands is fairly well assured. To obtain sufficient data to work out the outlet problem, it may be necessary to run some preliminary level lines to obtain elevations. Existing records of past high waters both as to height and quantity should be studied. With information such as has been mentioned, a preliminary plan can be worked out closely enough to determine the feasibility of carrying out drainage.

Development of the Final Plan.- If the preliminary investigations show that a drainage system will reclaim an area of wet land at a reasonable cost, ordinarily the engineer is instructed to design the plan for reclamation and to prepare such specifications as may be nesessary for carrying out the work.

In working out the final design, the data from which the preliminary plans were made usually has to be supplemented with a large amount of additional information. Survey parties must go into the field and run lines thruout the area, determining the elevations of the various portions of the territory, collecting high water marks and data, meandering the important streams, and in general securing complete information regarding whatever may affect the drainage situation.

The field data must be compiled and maps made showing the important topographic features and elevations.

Then the drainage system must be designed. To do this intelligently and to be sure that the plan will be effective, a thoro knowledge of the principles and applications of hydraulics of streams is needed. Space does not permit that a discussion of these principles be set down here. Suffice to say, however, that the engineer who seeks to lay out a large drainage system must be able to solve all problems dealing with the flow of water in both artificial and natural channels. Artificial channels are ordinarily based on the use of the Chezy formula and Kutter's formula for the roughness coefficient. The engineer should not only be able to solve correctly these formulas but he should also have developed judgment as to the particular Kutter coefficient to use in any case. To this end, he should be able to make field experiments on constructed channels to verify the coefficients used and to furnish data for future similar designs. The solution of the Chezy formula is best accomplished by means of diagrams and the engineer should understand the use of such diagrams.

Flow problems in natural channels requires the same knowledge and judgment in the application of the Chezy and Kutter formulas and in addition requires a thoro understanding of the solution of backwater problems. Perhaps no part of the drainage engineer's hydraulic knowledge is so essential as that of backwater for by means of backwater calculations determining elevations are found which influence the entire design.

It is not unusual for drainage systems to involve problems of storage of water in lakes or in artificial reservoirs. The engineer will find useful in this connection, a knowledge of the methods of computing capacities and areas of reservoirs and of determining their effect on stream flow.

Where levees are planned, sluiceways and inverted siphons are met with and the flow thru such structures must be investigated and proper designs worked out.

For a theoretical treatment of the subjects that have been mentioned as essential or useful to the drainage engineer, reference should be made to standard books on hydraulics.

After the drainage works have been designed, the next step is to estimate the cost. In this connection, it is quite necessary that the drainage engineer be able to estimate earthwork and other pieces of auxiliary drainage work. He must also be informed as to the prices that the work can be contracted for in order that his cost estimate may be accurate and dependable.

5.
ASSESSMENTS

Processes of Making Assessments.- There are two distinct divisions which are necessary in the making of a drainage assessment roll. The first is the fixing of the rate of the benefit which each tract of land to be assessed should bear. The second consists of listing the lands on the assessment roll form and calculating the total amount of benefit to be assessed against each tract of land. These divisions apply to the method which is the only rational one for making assessments, that of assessing benefits that will accrue by reason of an improvement. The discussion of assessments to follow will not consider any other method.

Fixing the rate of benefits is the only part of the work that requires experience and knowledge of the basis for making a just and equitable assessment. The compilation of the roll and the calculations of the individual benefits and taxes are only routine office work and, altho there are many points to be noted in connection with the efficient promotion of this work, this particular phase of assessments will not be taken up in this thesis .

The Benefit Method of Assessments.- The most equitable way to arrive at the benefit that each tract of land should be assessed is to determine the maximum amount of benefit that will be received by any of the land effected and to then assess benefits on other tracts of land in terms of a percentage of this maximum benefit. For illustration, the maximum benefit might be $30 per acre. Then this land would be considered as 100 per cent land.

Land that should be assessed only half as much as the land bearing the maximum assessment would then be classified as 50 per cent land and would bear a benefit assessment of $15 an acre. Land that would receive only seven tenths of the maximum benefit would be 70 per cent land and would be assessed for benefits $21 an acre. Other lands would be assessed in proportion to the benefit received.

The amount that will constitute the maximum benefit to be received differs according to the extent of the improvement and the original condition of the land improved and can not exceed the amount by which the value of the land will be enhanced after the improvements are carried out. It is usual in the South to fix the maximum benefit that will be received by lands in overflow areas where the soil is fertile at from $20 to $40 per acre. The actual benefit that is received is in most cases greater than this and greater benefits could be proven and sustained in court. However, these benefits will in most cases afford a sufficient margin between benefits and cost so that the security of the bond issue is assured and nothing would be gained from a practical standpoint by increasing the benefits.

Determining Factors in Assessing Benefits.- Before lands effected by a particular improvement can be assessed, it must first be determined what land will be most benefitted . This will then be 100 per cent land and will form the standard by which to assess the other lands. In the classification of lands according to the percentages which each tract should bear, eight factors need to be considered.

These eight factors are;

1. Degree of wetness or lack of natural drainage.
2. Completeness of drainage provided or distance to nearest outlet provided.
3. Distance from natural outlets.
4. Relative location.
5. Degree of inaccessibility.
6. Fertility.
7. Kind of property.
8. Health.

The first three of these factors are quite important and the others are, in most cases, of relatively small importance. In order to bring out the influence of each factor upon the assessed benefits, each of these will be taken up and explained.

Degree of Wetness or Lack of Natural Drainage.- This is the most important factor in determining the amount of benefit to be received by any tract of land. Unless land is actually wet and in need of drainage, it will not be benefitted to any great extent and hence should be assessed only a small or nominal minimum amount. It is usual to assess lands that are too wet for profitable cultivation at the maximum rate even tho they are cleared of timber and attempts are made to cultivate them. Lands that can be profitably cultivated but on which crops are frequently destroyed should be assessed at percents less than 100 according to the frequency of the losses. Lands that are only occasionally damaged because of imperfect drainage and on which crops are never entirely lost should be assessed at a fairly low rate such as from 20 to 30 per cent.

Completeness of Drainage Provided.- A consideration of this factor takes account primarily of the proximity of a tract of land to proposed ditches and the completeness with which the water will be removed. A tract lying immediately along a ditch which has a perfect outlet would be considered to be completely drained. A tract some distance from a ditch would not drain into the ditch so readily and hence would receive less benefit .It is usual to rate the second tier of 40 acre tracts back from a ditch at from 10 to 15 per cent less than the tier of 40 acre tracts next to the ditch. Succeeding tiers of 40 acre pieces would be reduced accordingly. However, if the right of way necessary for the ditch is not paid for, then the ordinary procedure is to assess the first row of tracts the same as the second on the assumption that the value of the right of way taken balances the decreased benefits derived by reason of the greater distance to the outlet. After a basis for assessment according to this factor has once been established in any particular case, then it is only a matter of mathematical calculation to determine the assessments against all tracts as regards this factor.

Distance from Natural Outlets.- The distance from natural outlets is a very important factor in determining the assessment upon a tract of land. Land may be extremely wet and yet be near a perfect outlet. For example, a wide flat ridge some 10 feet above the elevation of the surrounding country might contain a tract of land too wet for profitable cultivation and,nevertheless, this land would not be greatly benefitted by a drainage system because the land already has a natural outlet at the edge of the ridge and entirely independent of the outlet channels which may be cut thru the low ground along side. The work necessary to reclaim the tract could be done by the owner without regard to the carrying out of the improvements in the low land. Such circumstances would justify only a small assessment on the land. This land would be in the same class as land with a good outlet at an elevation well above any determining elevation of a system of proposed ditches.

Relative Location.- By relative location is meant the location of land with respect to the drainage system proposed. For example, the lands bordering on the upper ends of lateral ditches, which must necessarily be constructed larger than the hydraulic standards which govern the lower ends of the ditches require in order to permit the excavation to be done by the same equipment, will receive some more benefit than the lands along the lower stretches of the ditches because, even under extreme conditions which may cause the water to run full in the lower reaches of the ditches or to spread over the ground for several hours, the excess capacity in the upper ends of the ditches will make the adjacent lands safe from overflow. However, the difference in benefits from such a cause are more apparent than real and the relative location of land with respect to the drainage system is only of minor importance in the assessment of benefits.

Degree of Inaccessibility.- This factor has reference to the location of a tract of land with respect to other lands or locations such as railroad stations or towns which it is always desirable to have within easy access. In some cases, even tho the land itself may be high and dry, it may be made inaccessible by floodwaters covering to impassible depths, the only roads which connect the land with other places. Again it may be that an intervening swamp makes the maintenance of a road to the land almost impossible without draining the swamp. In such cases the benefit derived may be considerable.It is, however, rather of an intangible nature and difficult to fix in amount so that the benefit partakes of an indirectness which courts are slow to sustain.

Fertility.- This factor should consider the variation in fertility of lands to be benefitted by an improvement. In the South and in most other parts of the country, the ordinary drainage district is composed largely of overflowed lands, the soil of which is all fertile in almost the same degree and capable of producing similar crops. This being the case, there could be no variation of importance in the benefits derived as a result of any difference in fertility of soil. If there should happen to be a barren tract of land that cannot be profitably cultivated to produce as great returns after drainage as the rest of the lands, then this tract should not be assessed at all or in any event only a small amount.

Kind of Property.- The use to which a piece of property is or may be put affects the benefit received by that property. Where land is high in price and used for intensive purposes and where the lowering of the water level in the ground might make it of greater value for building or other purposes than it would be for agricultural uses, then the benefit received would be high and should be assessed against the land. In the ordinary drainage district, however, such cases are not likely to arise, for all of the land is usually valuable chiefly from an agricultural standpoint.

Health.- There are always bodies of stagnant water which are drained away by drainage improvements. These places are always breeding places for disease carrying species of insects such as the malarial mosquito. When drained and removed, the community receives a benefit. This is more or less the same thruout any area that is improved at one time and hence need not be given much consideration in placing the benefit assessment.

Combination of Factors.- As has been stated previously, the first three named factors are the most important. In making an assessment, the factors are combined according to their relative importance into one final per cent of benefit which is placed against the particular tract being considered. This final per cent may be obtained mathematically by rating the various factors and combining them but inasmuchas errors in judgment in determining the factors themselves are liable to be as great or greater than any error in mentally fixing the final figure directly from a mental consideration of all the factors, it is not usual to use any extended mathematical processes in arriving at the desired result.

Special Cases of Assessments.- Railroads and town lots in a drainage district constitute a special class of property which must be assessed somewhat differently from ordinary lands. Town lots are quite often assessed a flat low rate. Railroads may receive benefits because drainage will decrease the maintenance costs for the part of the line within a drainage district. They may be benefitted by reason of the necessity no longer existing to maintain long and expensive trestles to pass flood waters. Such things as these are direct benefits. Railroads also always receive an indirect benefit from the increased prosperity which results from drainage improvements. It is a matter of extreme difficulty, however, to sustain any indirect benefits in court. It is customary in many districts to assess the railroad property at the maximum acreage per cent for the total number of acres of railroad right of way within the district.

6.

FINANCING DRAINAGE DISTRICTS

Methods.- Whenever drainage district improvements are to be carried out, money must be provided to pay for the cost of the work. Such improvements usually cost large sums of money and the landowners are not ordinarily financially able or disposed to make payment themselves for the drainage works at the time they are constructed. What is desired is to lessen the burden of payments by extending them over a period of years which may occupy the larger part of the life of the improvement. This result may best be attained by paying for the work in the first place with funds realized by issuing bonds. The bonds are then retired in the course of several years by money raised by taxation.

Drainage laws usually provide for allowing any landowner to pay his entire assessment before the improvements are built but except on very small pieces of work, this is never done. Where drainage work is done under county ditch laws, it sometimes happens that the county issues certificates of indebtedness called script to pay for the work. These certificates are payable whenever there are funds available from the collection of taxes .

Issuing bonds is by far the most important method of financing drainage districts and the other means will not be considered further.

Security for Drainage Bonds.- Bonds issued for drainage improvements are secured by what is virtually a mortgage on each tract of land assessed to the extent to which each tract participates in paying for the improvement . The bond issue is not secured by the full value of the property within a district but only by an amount equal to the benefits assessed against the lands. Each parcel of land is individually liable only to the extent of the benefits which it bears as shown by the assessment, and whenever any piece of land has paid an amount equal to the benefits received, then its liability ceases. In drainage districts, there is usually an ample margin between the benefits and the cost,which is the amount of the bond issue,so that the security of the issue is not to be doubted.

Bond buyers scrutinize the benefits and their relation to the cost of the work in order to satisfy themselves that the benefits assessed will actually be received and that the cost is not too great a per cent of the benefits.

Approval of Legal Proceedings.- There are in this country, a few legal firms of unquestioned high standing, whose approval of all the legal steps taken in the organization and forwarding of the district affairs of a drainage district must be secured before bonds will be paid for by the bond buyer. These firms have specialized in familiarizing themselves with the correct legal procedure under the laws of the different states . The bond purchaser usually buys an issue conditional upon the securing of the approval of some one of these legal firms.

The importance of this approval is evident when it is remembered that unless each particular step in the proceedings of a district is in accordance with the law, the securities will have no standing in court and the bonds will be valueless. Unless bond dealers were thus careful in making sure that the legality of the procedure was unquestioned, it might develop that some flaw would be brot to light years after the issue had been made that would vitiate the bonds even at that time. In order to be able to offer their clients bonds which are absolutely secure, the bond dealers must have satisfied themselves that the legal steps are accurately and precisely taken.

Approval of the Plans.- Another feature of the work that the bond man must investigate is whether the improvements that are proposed have been planned so that, when completed, they will give the results intended and benefit the lands as much as the assessed benefits. The reputation of the engineer planning the improvements is always considered by the purchaser. If the nature of the work is not especially large or unusual in character, if the engineer is one of standing then this in itself will serve to convince the bond man that the plan is satisfactory and worth the cost. However, if the engineer is not well known or of an established good reputation, or if the work is more than ordinary in character or cost, then the dealer in bonds will employ competent engineers to check over the plans and determine their feasibility and correctness.

The approval of the plans is important because, if the improvement should fail, then the purchasers of the bonds would find themselves without security for the money which they have loaned.

Naming a District.- In selecting a name for a newly organized drainage district, no such name as the "Wild Cat Slough Drainage District" should be selected. The name chosen may have a real effect on the sale of the bonds for , as a bond dealer once told me, it is not an easy matter to convince a man to buy bonds of a "Wild Cat Slough District" when the money with which he makes the purchase may represent the savings of several years. The name should instead of being of a wild-cat nature, be more conservative and give an impression of substantial prosperity and financial backing.

Details of Bond Issue.- Bonds are usually issued as serial bonds, which means that the bonds fall due in series, some each year until the entire issue is retired. Drainage bonds are quite usually issued so that none of the bonds fall due for at least 5 years after the date of issue, only the interest being paid for the first 5 years. This allows the landowner to meet the heavy expense of clearing the land during the early years. Then, by the time the tax becomes heavier to pay off part of the bond principal, the land is in cultivation and yielding returns with which to meet the increased taxes.

Before the bonds are sold, the exact amount of the issue, the rate of interest, the dates of maturity, the place of payment, and the denomination of the bonds should all be determined. The maturities should be so arranged that the sum of the interest and principal payments will be practically the same for each year following the years when only interest is paid.

7.

EXCAVATING EQUIPMENT

Classification.- The construction of canals and levees to accomplish reclamation of overflowed lands is done by several different types of equipment, the equipment in any particular case depending upon the nature and conditions of the work. Mr. Charles Prelini in his book, "Dredges and Dredging", has classified excavating machines into two kinds, continuous and intermittent. In the first class are placed ladder dredges, hydraulic dredges, stirring dredges and pneumatic dredges; in the second class are dipper dredges and grapple dredges. Professor A.B. McDaniel in his able work, "Excavating Machinery", has divided his subject into, first, scrapers, graders and shovels, and, second, dredges. The first includes the various kinds of scrapers and graders, capstan plows and steam shovels; the second includes dry land excavators, floating excavators, trench excavators, and levee builders.

A classification different from either of these will be used in this thesis. This is given on the following page. The foundation for this classification is, first, the method of excavating and, second, the means of locomotion. With this division, not only are machines operating on similar principles brot together but the equipment classified under each main heading arranges itself, with a few exceptions, in the order of the relative importance of each type from the standpoint of land reclamation.

CLASSIFICATION OF EARTH MOVING EQUIPMENT

A. STIFF ARM MACHINES

1. Steam Shovel

2. Dipper Dredge
    a. Floating
    b. Land

3. Walking Dredge

4. Drag Boat

B. SUSPENDED CABLE MACHINES

1. Drag Line
    a. Mounted on Tracks, Rollers, or Wheels
    b. Walking
    c. Guided Bucket
    d. Tractor

2. Tower Machines

3. Grapple Dredges

C. REVOLVING WHEEL OR CHAIN MACHINES

1. Templet Excavators

2. Wheel Excavators

3. Trench Excavators

4. Ladder Dredge

D. HAND AND TEAM

1. Scrapers

2. Graders

3. Plows
    a. Capstan
    b. Trench

4. Shovels

E. HYDRAULIC MACHINES

1. Suction Dredge

F. MISCELLANEOUS

1. Dynamite

A.- STIFF ARM MACHINES

1.Steam Shovel

Description.- There are two principal types of steam shovels- railroad shovels and revolving shovels . The former are of very heavy construction and are built on the lines of a railroad car, the shovel operating from one end. Revolving shovels are of lighter construction and built to permit complete rotation of the entire shovel and machinery thru a full circle. Both types require the excavated material to be rehandled and disposed of by dump cars or other means.

The usual type of shovel consists of a steel frame mounted upon trucks and carrying the machinery for excavating. A cab or housing built over the frame shelters and protects the operating mechanism. On the front end of the frame, a boom projects upward at an angle of approximately 30 degrees or more. On the large size shovels, the point of the boom is supported by a cable hung from a triangular shaped A-frame which extends several feet above the top of the housing. On small shovels, the boom is hung from a frame at the elevation of the top of the cab. Suspended from the end of the boom is a steel dipper which works on a long handle passing thru the boom. The dipper handle has a rack on its under side which engages in cogs on a shipper shaft where the handle goes thru the boom.

Three sets of engines are employed on a steam shovel. Hoisting engines operate the hoisting drums upon which are wound the cable that hoists the dipper. Swinging engines operate the swinging drums which revolve the shovel . On railroad shovels, only the boom and dipper revolve and these travel only thru a few degrees more than 180. On revolving shovels, the entire body of the shovel can revolve thru a full circle. Crowding engines are the third set of engines required. These engines apply a force to the dipper handle to crowd the dipper into the material being excavated.

On the rear of the shovel is the boiler. Large shovels

Locomotive Type Steam Shovel In Operation

employ locomotive type of boilers and small shovels use vertical tube boilers. Some shovels are electrically operated and require no boiler.

Railroad shovels are mounted on standard gage trucks. Revolving shovels may either be mounted on broad traction wheels or on standard railroad wheels. In the latter case, theshovel moves on short sections of track which are moved from behind the shovel and relaid in front when the shovel is moved ahead.

Either chains or cables are used for swinging the boom and hoisting the dipper. The dipper is usually equipped with manganese steel teeth to facilitate digging. The back of the dipper is hinged or latched. The dipper is emptied by tripping the latch. On various types of shovels, jack arms are used to anchor the machine and hold it steady. These arms project from the side of the frame and bear against the ground along side.

Revolving Steam Shovel And Railway
Building Mississippi River Levee

Steam shovels in ordinary use are manufactured with booms from 16 to 90 feet long and with dippers holding from 5/8 to 6 cubic yards.

Uses.- Steam shovels have a multitude of uses wherever earth and rock are excavated. It is not within the scope of this thesis to discuss these uses except as they may pertain to the reclaiming of overflowed lands. In this connection, steam shovels have been found useful in excavating large canals where the material excavated could be loaded into dump cars and hauled away. For the ordinary sized canal, however, other equipment is better adapted than the steam shovel.

The chief use of a steam shovel insofar as the reclaiming of waste lands is concerned is in the construction of levees.

Another View Of Steam Shovel And Railway
Building Mississippi River Levee

Two illustrations are shown here of a steam shovel and industrial railway used together in building a levee along the Mississippi River. In this particular instance, suitable material for the levee could not be secured immediately adjacent to the levee on the river side. A track was laid from a pit about a quarter of a mile distant and a steam shovel was installed to excavate the material for the levee. It is in such cases as this that the steam shovel is most useful in land reclamation.

2.Dipper Dredge

a-Floating

Description.- Foremost in importance among all kinds of excavating machinery used for reclaiming land from swampy conditions is the floating dipper dredge. The dipper dredge is in effect a steam shovel mounted on a floating hull and with the details modified to suit the change. There are two general classes of floating dipper dredges: dredges for drainage and irrigation canals and deep water dredges for use in harbors and rivers. The chief difference between the two is that the latter is designed to dig from 25 to 50 feet below the water surface. Deep water dredges are also built with more substantial housings to provide living quarters for the crew on the boat. Dredges used for swamp canals ordinarily have only sufficient housing to protect the machinery and the crew lives in a cabin boat which floats along in the ditch behind the dredge.

Deep water dredges empty the excavated material into scows which are towed away and dumped . The drainage ditch machine places the material in spoil banks along the sides of the ditch.

Dipper dredges may be floated either on a wooden hull or a steel one. Wooden hulls cannot be moved from job to job due to their bulk and the expense of tearing to pieces. Hence a new hull must be built on each new job. Steel hulls are sectional and are transported from one job to the next. They may be used until worn out. Properly designed steel hulls require much less looking after on the work than do wooden hulls which must be watched closely to stop up the leaks which always occur. The steel hull also is lighter in weight than the wooden hull and draws less water. This is partly offset by the greater stability gained by the weight of the wood hull.

Deep Water Dipper Dredge

The boom of the dipper dredge is hung from an A-frame in a manner similar to the railroad steam shovel. Booms are either solid wood trussed with steel rods and reinforced with steel plates or are built up steel shapes, latticed and trussed. The A-frame of the dipper dredge is subjected to very heavy strains and must be built very strong. The dipper and dipper handle are similar to the same parts of the steam shovel except that the crowding motion is not used on the drainage dredges. Many dippers have a heavy manganese lip instead of teeth.

In excavating, a dredge is "pinned up" and held steady by means of spuds which may be either bank or vertical. Bank spuds are heavy timber members which extend like two legs of a right angled triangle from the side of the boat near the front . The in-

Floating Dipper Dredge Digging Drainage Canal

clined leg of the triangle rests on a spud foot on the bank and inclines inward and upward toward the boat. Where the excavation is too wide to permit the spud foot resting on the bank, vertical spuds are used. These are very large timbers which extend vertically along the side of the boat at the front and slide up and down in guides or wells. A rear vertical spud is used in all cases whether the other spuds are bank or vertical. In the digging position, the spuds are lowered and pressure exerted thru them until the weight of the boat is largely carried directly on the spuds. The spuds are therefore a very important part of the dredge . When the loaded dipper swings to the side to discharge its load, very heavy strains are produced in the spud on the side to which the dipper swings.

The engines on a dredge consist of hoisting, swinging and spud engines. The first hoist the dipper, the second swing the boom and dipper, and the third operate the spuds. Sometimes the spud engines are omitted and the spuds are raised and lowered by the hoisting engines.

Boilers used on dregdes are either locomotive or Scotch marine type. Where conditions adverse to steam drive are encountered, dredges may be either oil or electrically operated.

Three methods of attaching the dipper to the boom are in use, the triple, double, and single hitch. These methods refer to the number of strands of cable used between the point of the boom and the dipper. The diameter of the winding drums is dependent upon the type of hitch used.

Dipper dredges are made in a variety of sizes and dimensions. The size of a dredge is usually referred to by giving the boom length and the rated dipper capacity. Booms are made from 20 to 100 feet long and dippers from 1/2 to 6 cubic yards capacity for ordinary use. Harbor dredges are equipped with extra large dippers holding up to 15 cubic yards.

Uses.- Dipper dredges are used on drainage work wherever it is desired to excavate material which may be placed along the banks of the excavated channel. This statement must be limited to the extent that on very large channels, the amount of material to be removed is so great that the dredge cannot place the material properly on the banks. The limiting size of channel is when the cross sectional area of the ditch becomes greater than about 1250 square feet. In the construction of very large channels, a heavy spoil bank is formed which, in alluvial soils, tends to cave and break off and slide into the excavated ditch. For very large channels, then, the present dipper dredge is not well adapted and other types of equipment are ordinarily selected for the construction of such channels.

The maximum size of ditch that can be dug with a dipper dredge economically is one with a cross sectional area of about 500 or 600 square feet, that is a ditch about 40 feet on the bottom and 10 feet deep. This size is the most economical to dig but the dredge can excavate much smaller and much larger ditches cheaper than most of its competitors. The minimum sized ditch that a dredge can dig has a sectional area of from 125 to 150 square feet. It is quite often cheaper to dig a minimum dredge ditch than it is to dig much smaller ditches by some other means, altho the larger sized ditch which the dredge must cut to permit the hull to float in the ditch is not required from a hydraulic engineering standpoint.

In addition to making ditches, the dipper dredge is very useful in the construction of levees, particularly where the borrow pit is also to be used for a drainage ditch.

Deep water dredges are of use in dredging new channels in harbors and in maintaining channels in harbors and rivers. These dredges are also used for constructing large cutoff channels in big streams where the excavated material can be towed away on scows and dumped in a deep portion of the river.

For excavating earth in heavily timbered lands, the floating dipper dredge stands alone due in a great measure to the enormous strength and power which it can develop in handling the huge stumps which are met with.

Performance.- The performance of the drainage dipper dredge is dependent on several factors. Chief among these is the water supply for a dredge is helpless so far as running is concerned without a sufficient supply of water to float the boat. During the dry season when the ground water table is low, dredges are forced to lie idle for months until rains come and fill up the country again and put water in the ditches. These forced shut downs affect greatly the progress of the work. On many contracts, dams are installed in the ditches to hold up the water level. It is quite often more economical to install pumps and provide sufficient water for operation by this means than to shut down and suffer the loss of several idle weeks.

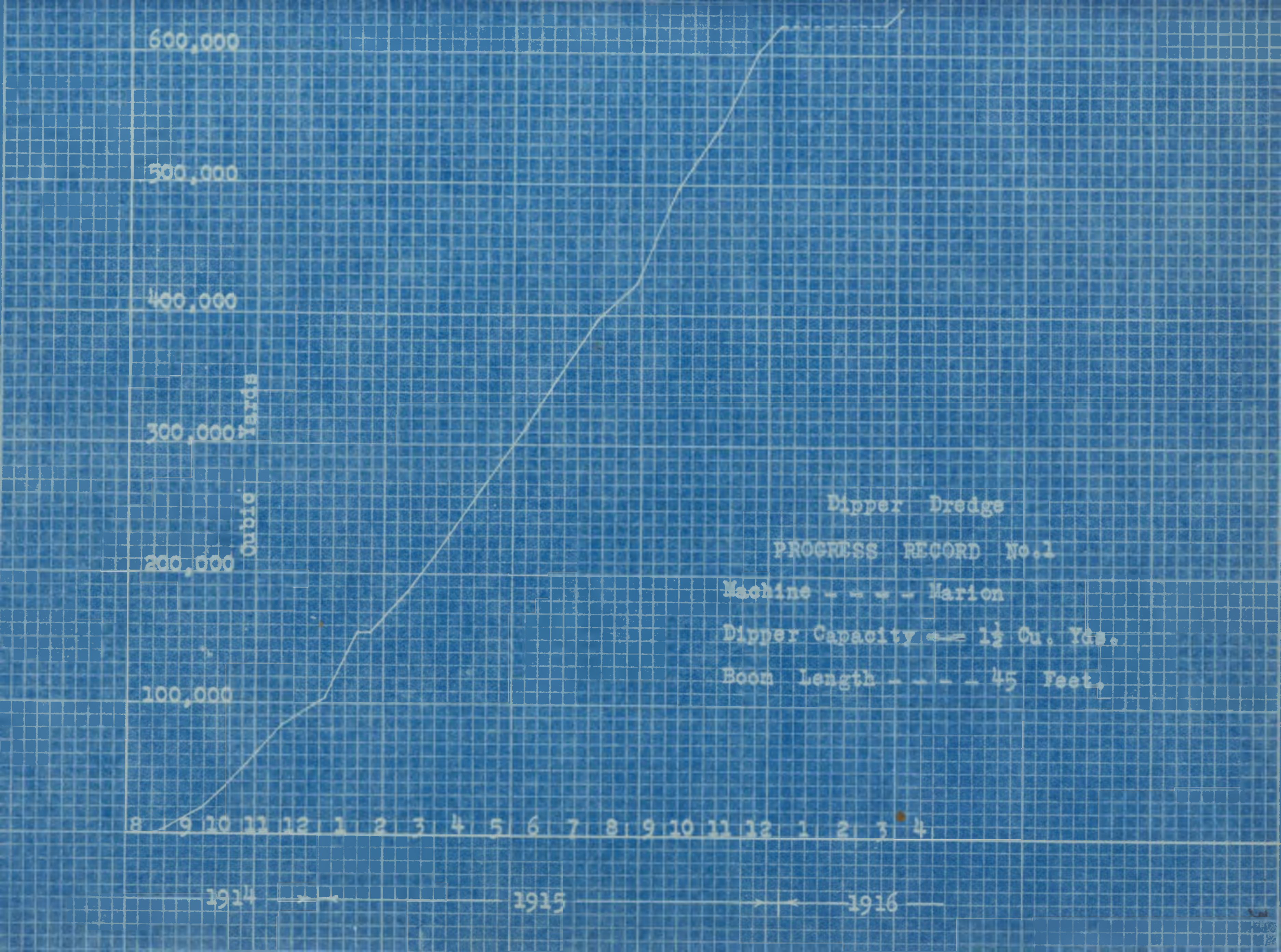
Break downs and repairs also play an important part in delaying the furtherance of the work. As in every pursuit, management is a factor that can greatly influence the success of operations . In dredge work especially is this true for the work is usually performed under difficult conditions and under the handicap of being out in the swamps and removed from habitations. To keep the dredge in repair and in good running order requires the exhibition of no little skill of management and many poor records have been made because of the fact that the superintendent was lacking in the qualities necessary for a good manager.

On the pages immediately following are a collection of the progress records of a considerable number of dredges of various sizes and makes. The leading facts concerning the conditions under which these records were made are set forth in the accompanying table.

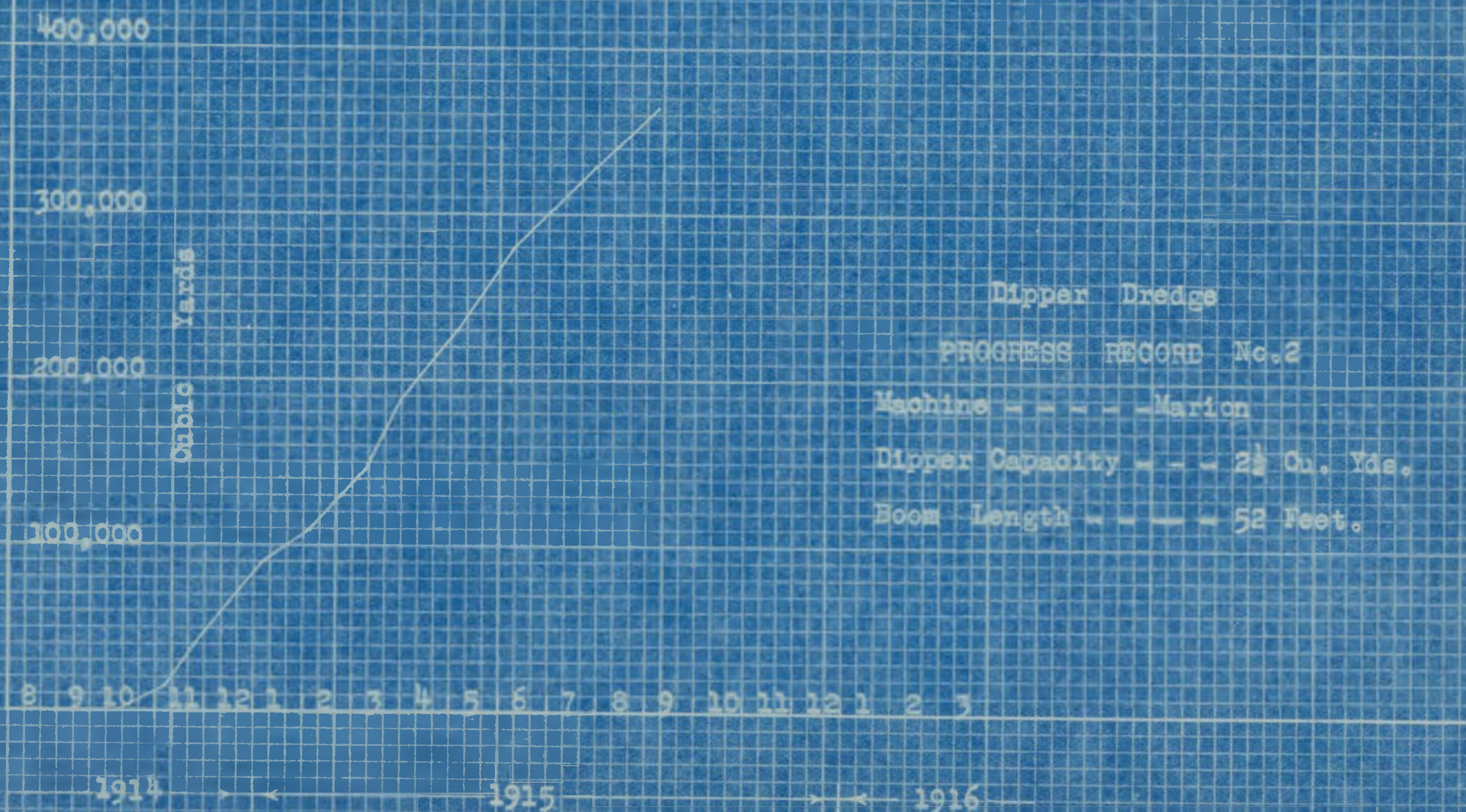
In planning a drainage system, the engineer is called upon to determine what rate of progress shall be required on the various parts of the work. The best method in handling this matter is to specify a rate of 25,000 or 30,000 cubic yards per month shall be required for ditches from 10 to 20 feet wide on the bottom and then to increase the rate up to about 80,000 cubic yards per month for the largest sized channels. The specifications should also provide for extensions of time due to conditions over which the contractor has no control such as lack of sufficient water to operate. Under the most favorable conditions, the above named rates may be considerably exceeded. For example, it will be noted that on progress Record Number 23 the machine during one month moved over 150,000 cubic yards of earth. This, however, was an exceptional month and all the conditions fitted in to make the high run possible. The effect of good superintendence is especially prominent in this record. No such high rate could be maintained thruout a job and it is much fairer and better to specify a rate that can be maintained under average working conditions and with average superintendence than to require a rate which cannot be kept up under average conditions and which will cause endless arguments and disputes with the contractor if he falls behind the specified rate.

TABLE OF INFORMATION
TO ACCOMPANY
DIPPER DREDGE PROGRESS RECORDS

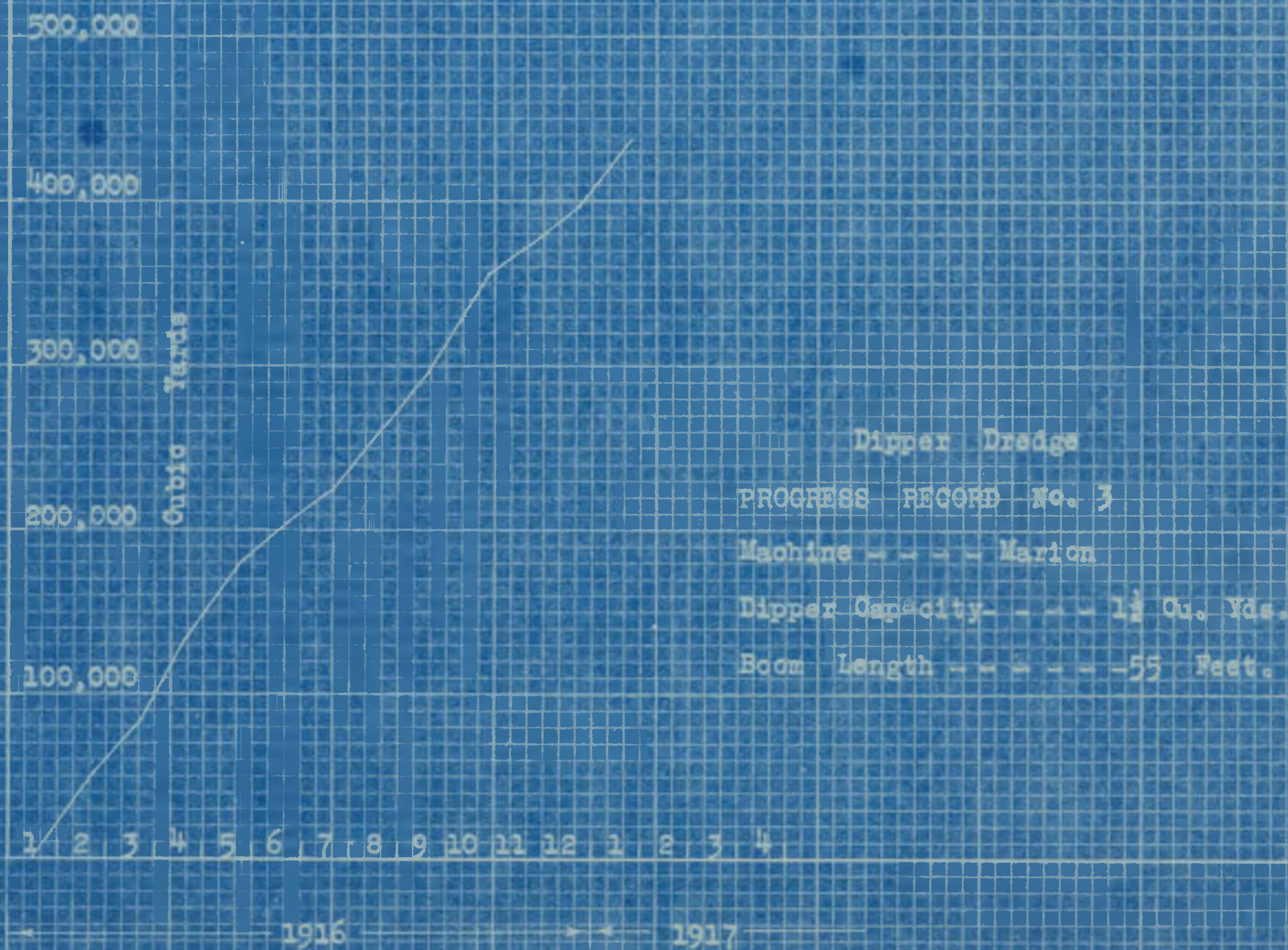
Progress Record No.	Location of Work	Total Excavation Paid For (Cu. Yds)	Dimensions of Work: Bottom Width (Ft.)	Dimensions of Work: Average Depth (Ft.)
1	Central Arkansas	636,000	12 - 16	8.5
2	Central Arkansas	364,000	12	8.0
3	West Tennessee	438,000		
4	West Tennessee	209,000		
5	West Tennessee	366,000		
6	West Tennessee	862,000		
7	Central Miss.	355,000	14 - 20	8.0
8	Central Miss.	94,000	14	5.5 - 8.5
9	Central Miss.	221,000	25	16.5
10	Central Miss.	480,000	14 - 16	6.0 - 9.0
11	Central Miss.	701,000	14 - 28	4.5 - 13.0
12	Central Miss.	165,000	14	8.5
13	Central Miss.	258,000	14	6.0 - 9.0
14	Central Miss.	342,000	14	8.5 - 11.0
15	Central Miss.	1,397,000	70	10.5 - 14.0
16	Central Miss.	681,000	14 - 20	2.0 - 10.5
17	Central Miss.	420,000	14	2.0 - 8.5
18	Eastern Arkansas	1,075,000	14 - 22	4.0 - 11.2
19	Eastern Arkansas	732,000	14 - 20	8.5
20	Eastern Arkansas	342,000	14	8.5
21	Eastern Arkansas	435,000	14 - 24	8.5 - 11.2
22	Eastern Arkansas	478,000	14	8.5
23	Eastern Arkansas	2,843,000	24 - 40	10.8 - 13.2
24	Eastern Arkansas	985,000	14	8.5
25	Eastern Arkansas	2,132,000	14 - 30	7.9 - 14.8
26	Eastern Arkansas	865,000	14 - 28	3.0 - 10.0
27	Eastern Arkansas	100,000	14	8.5 - 9.0
28	Eastern Arkansas	1,822,000	40 - 50	12.0 - 14.3
29	Eastern Arkansas	1,268,000	14 - 22	8.5 - 11.6

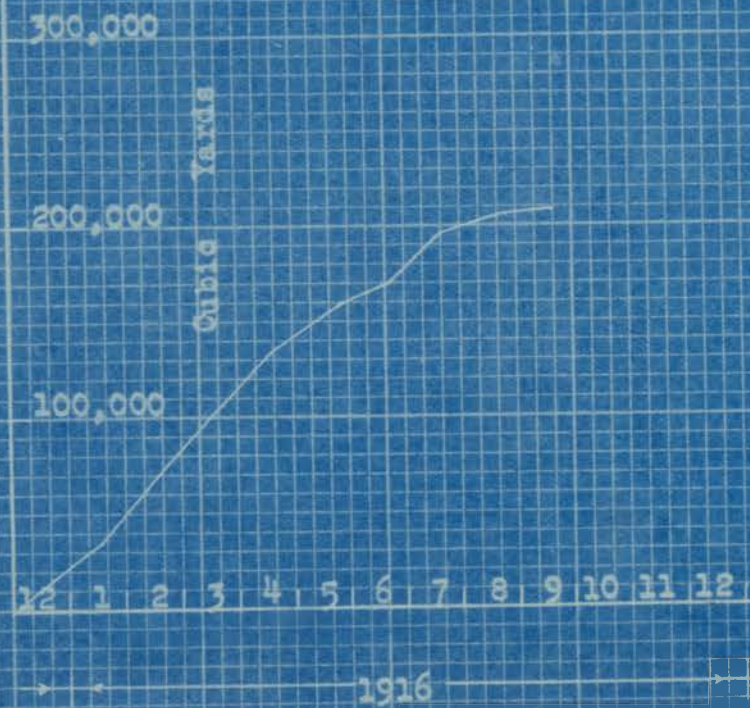


600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
1914
1915
1916
Dipper Dredge
PROGRESS RECORD No.1
Machine - - - - Marion
Dipper Capacity - - 1½ Cu. Yds.
Boom Length - - - - 45 Feet.



400,000
300,000
200,000
100,000
Cubic Yards
8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
1914
1915
1916
Dipper Dredge
PROGRESS RECORD No.2
Machine - - - - -Marion
Dipper Capacity - - - 2½ Cu. Yds.
Boom Length - - - - 52 Feet.


500,000
400,000
300,000
200,000
100,000
Cubic Yards
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
1916
1917
Dipper Dredge
PROGRESS RECORD No. 3
Machine - - - - Marion
Dipper Capacity- - - - 1½ Cu. Yds.
Boom Length - - - - - -55 Feet.



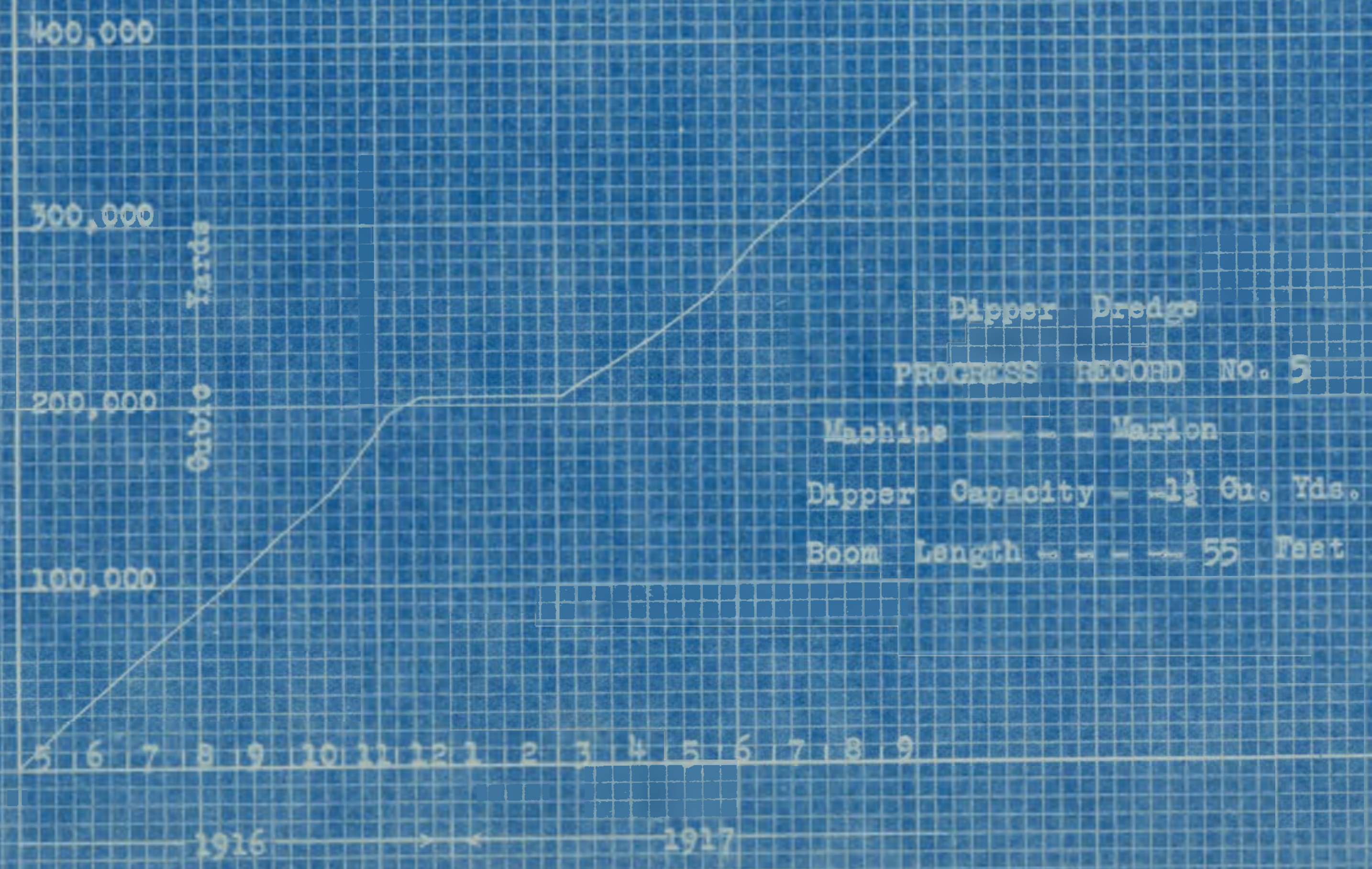
Dipper Dredge

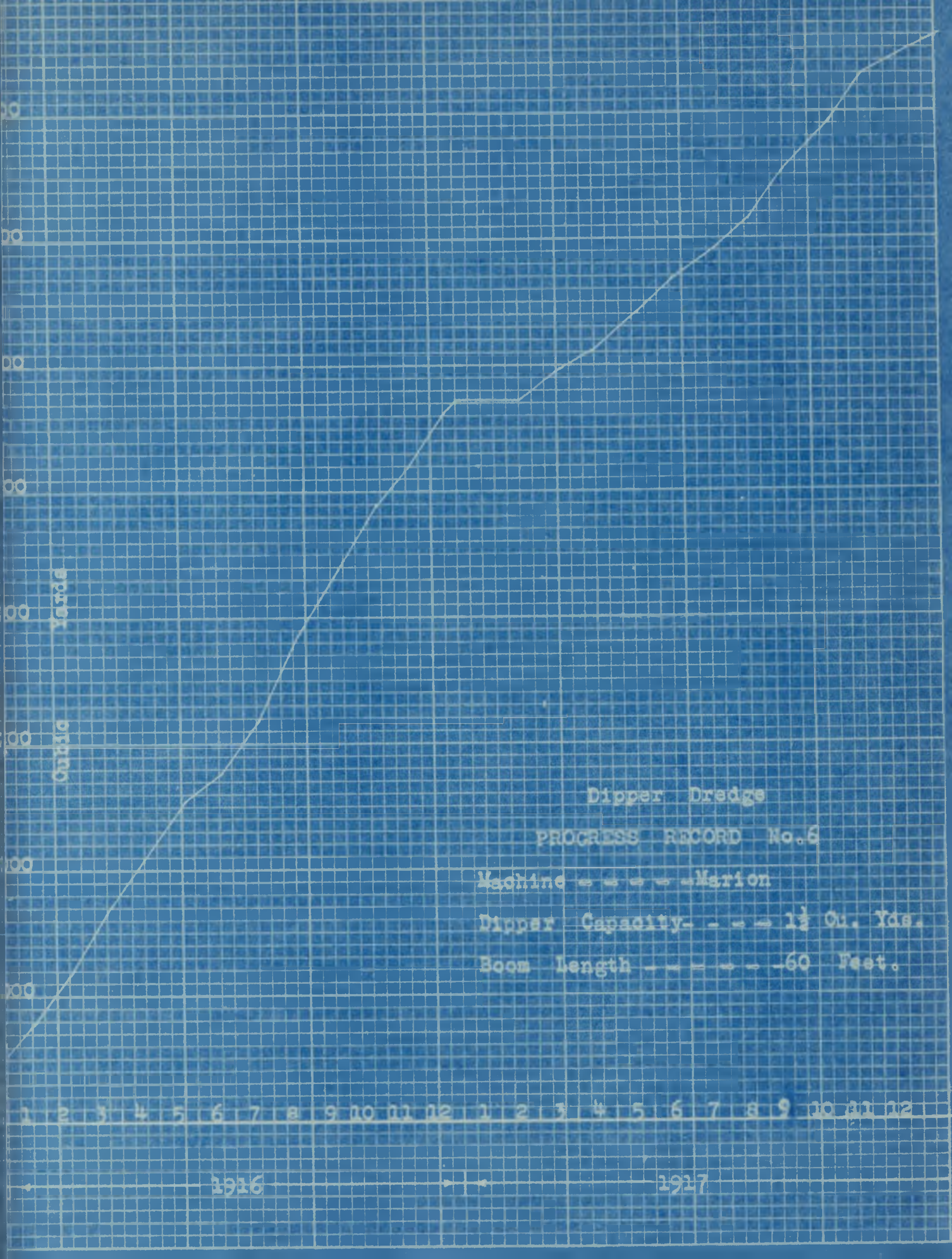
PROGRESS RECORD No. 4

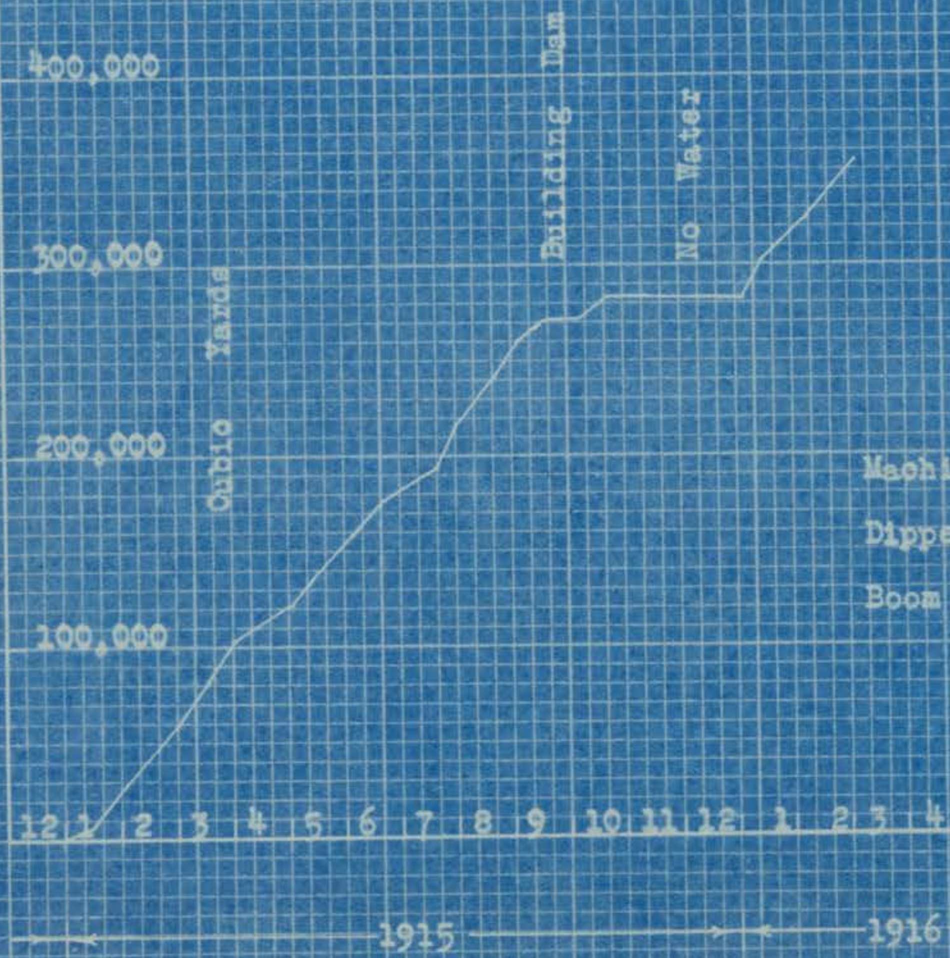
Machine - - - - - Fairbanks

Dipper Capacity - - - 1 Cu. Yd.

Boom Length - - - - - 40 Feet.


400,000
300,000
200,000
100,000
Cubic Yards
5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
1916
1917
Dipper Dredge
PROGRESS RECORD No. 5
Machine - - - Marion
Dipper Capacity - - $1\frac{1}{2}$ Cu. Yds.
Boom Length - - - - 55 Feet


Cubic Yards
Dipper Dredge
PROGRESS RECORD No.6
Machine - - - - - Marion
Dipper Capacity- - - - 1½ Cu. Yds.
Boom Length - - - - - -60 Feet.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1916
1917



Dipper Dredge

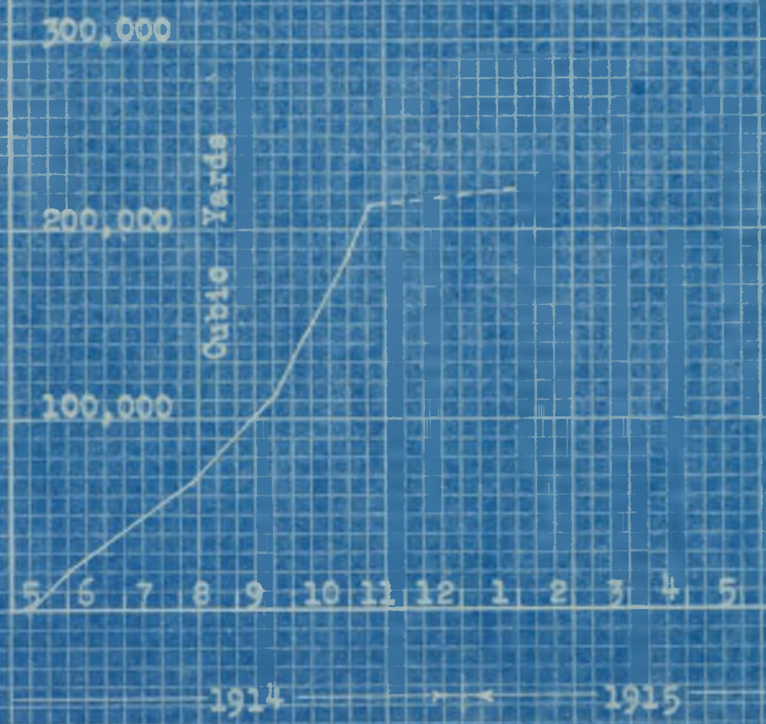
PROGRESS RECORD No. 7

Machine - - - - - - - - - - - Fairbanks

Dipper Capacity - - - - - 1½ Cu. Yds.

Boom Lebgth - - - - - - - - 50 Feet.


Dipper Dredge
PROGRESS RECORD No. 8
Machine - - - - - - - - - - - - Marion
Dipper Capacity - - - - - - ¾ Cu. Yd.
Boom Length - - - - - - - - - - 36 Feet.
200,000
100,000
Cubic Yards
Moving from one Ditch to Another
No Water
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3
1915
1916



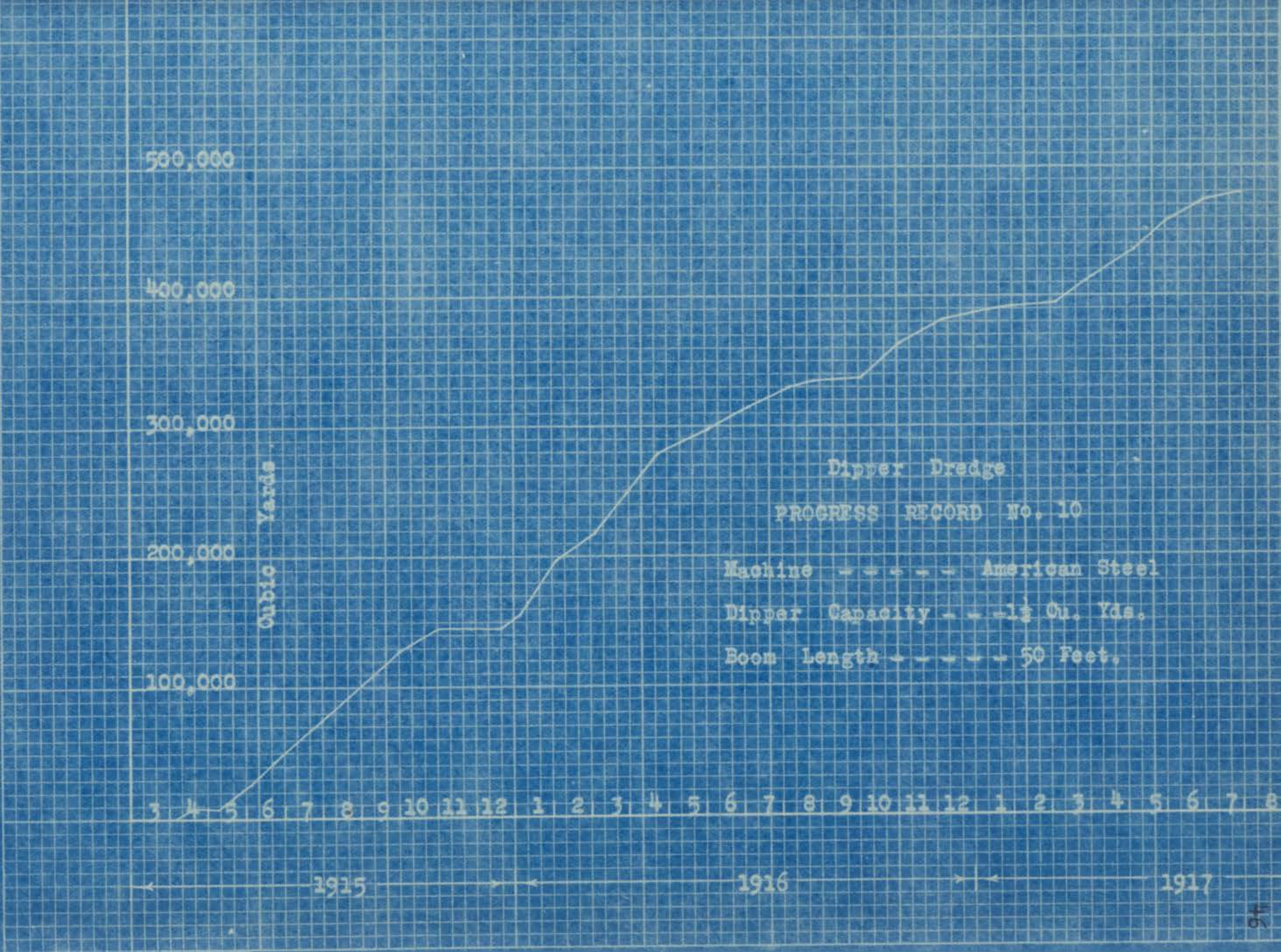
Dipper Dredge

PROGRESS RECORD No. 9

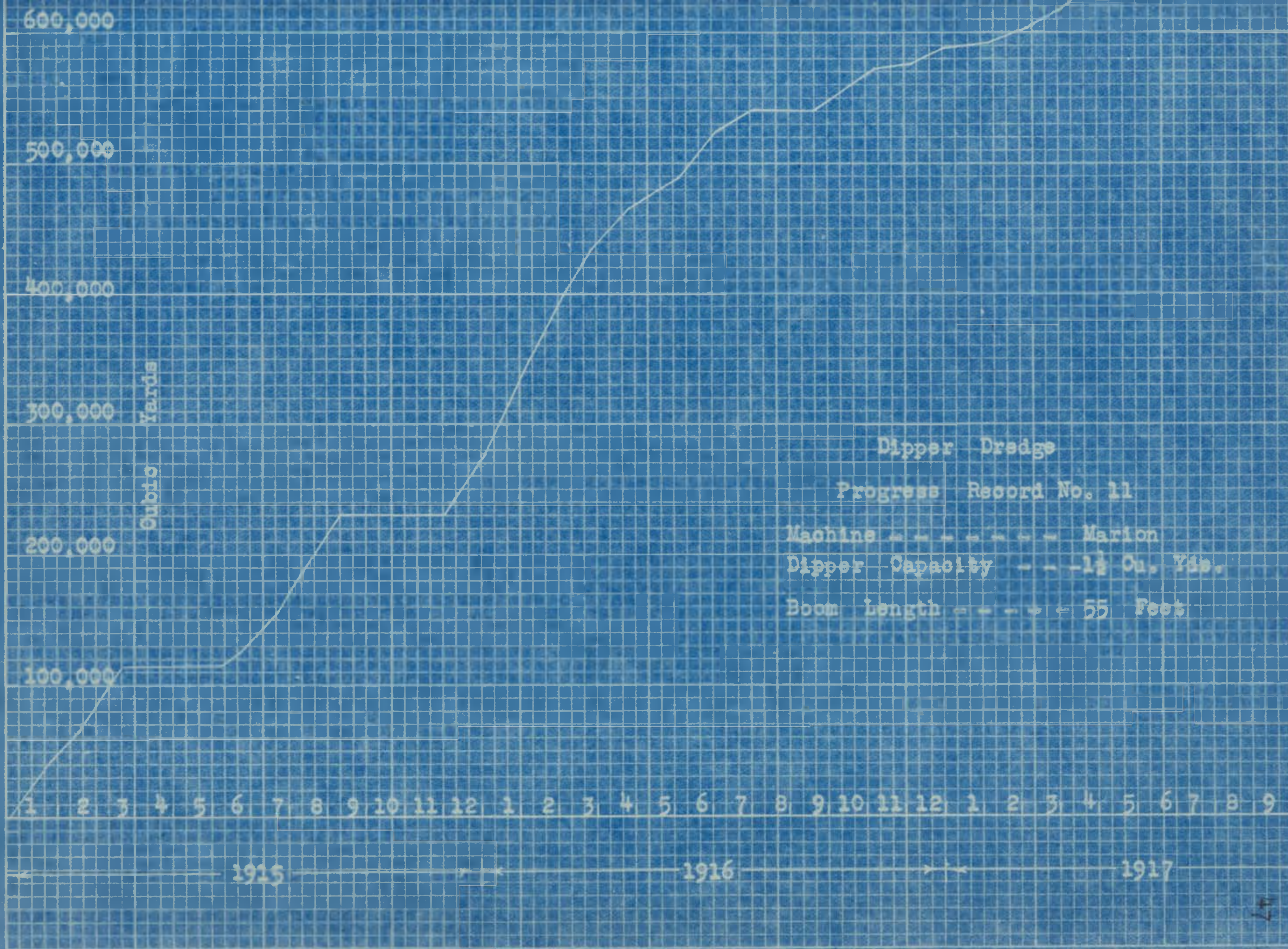
Machine - - - - - - - - - - Bucyrus

Dipper Capacity - - - - - - $2\frac{1}{2}$ Cu. Yds.

Boom Length - - - - - - - - -85 Feet.



500,000
400,000
300,000
200,000
100,000
Cubic Yards
Dipper Dredge
PROGRESS RECORD No. 10
Machine - - - - - American Steel
Dipper Capacity - - -1½ Cu. Yds.
Boom Length - - - - - 50 Feet.
3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8
1915
1916
1917


600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
1915
1916
1917
Dipper Dredge
Progress Record No. 11
Machine - - - - - - - - Marion
Dipper Capacity - - -1½ Cu. Yds.
Boom Length - - - - - 55 Feet

Dipper Dredge

PROGRESS RECORD NO. 12

Machine - - - - - - Marion

Dipper Capacity --- 1½ Cu. Yds.

Boom Length - - - - -45 Feet.

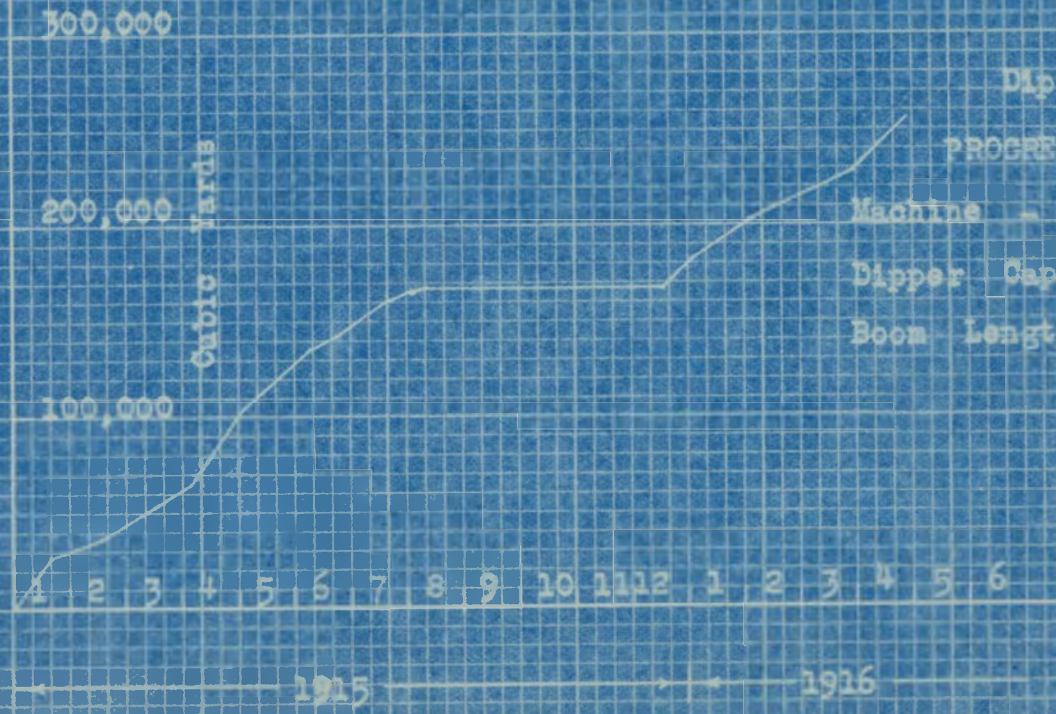
Dipper Dredge

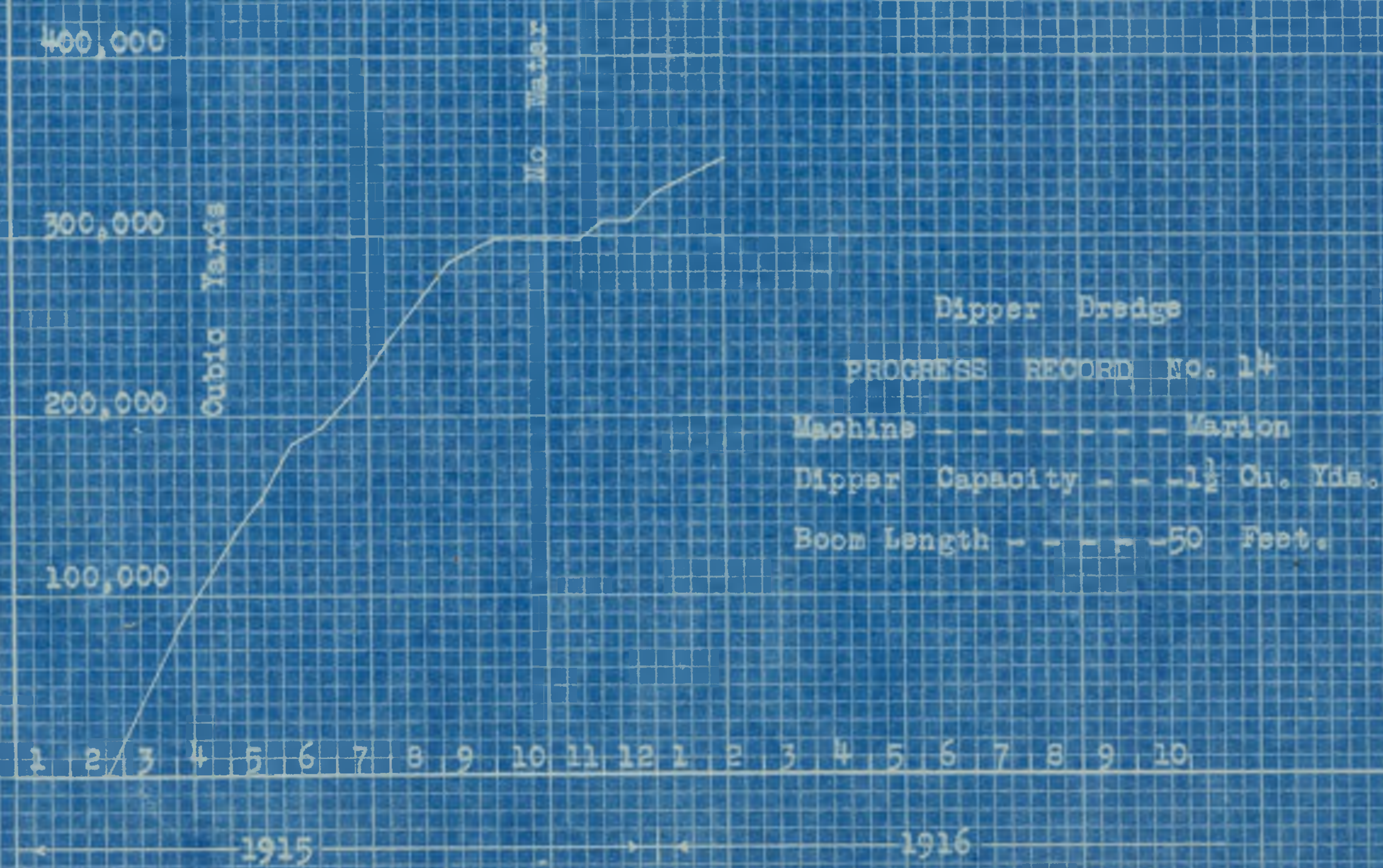
PROGRESS RECORD No. 13

Machine - - - Fairbanks

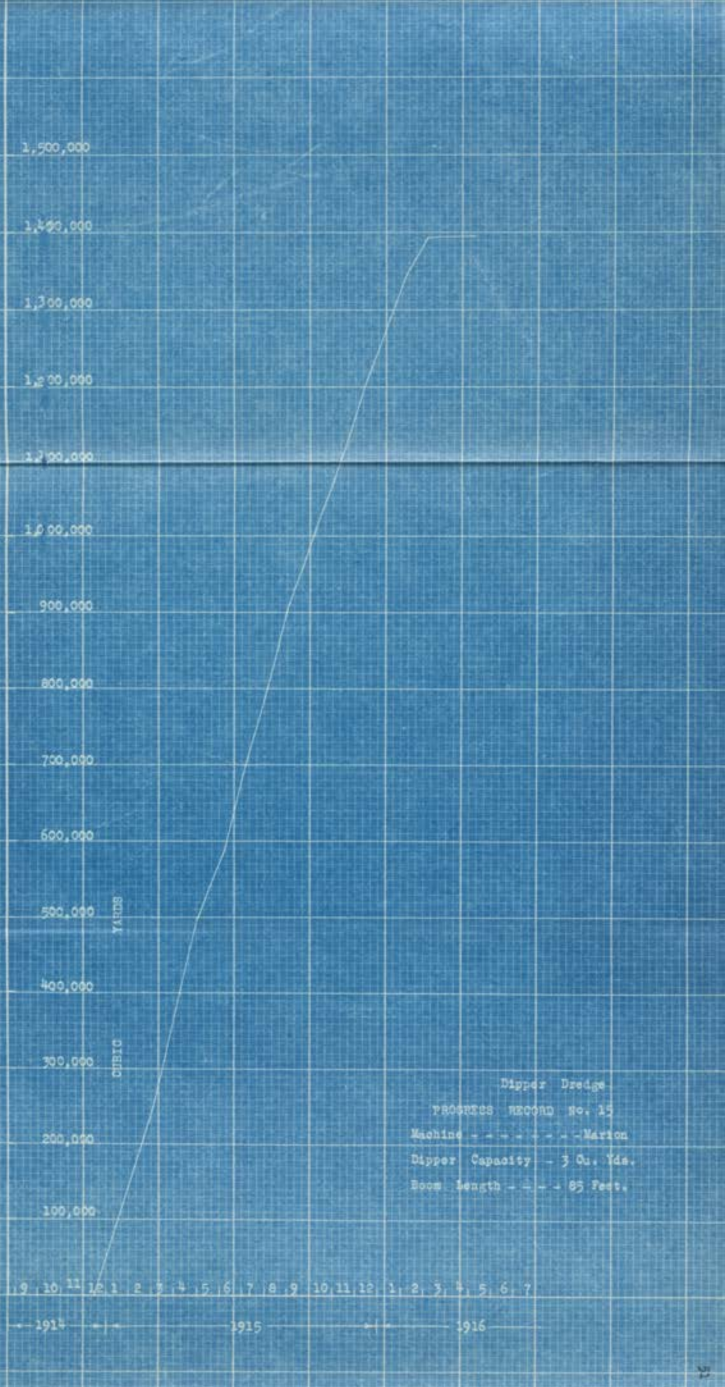
Dipper Capacity - - - 1 Cu. Yd.

Boom Length - - - - - 40 Feet.

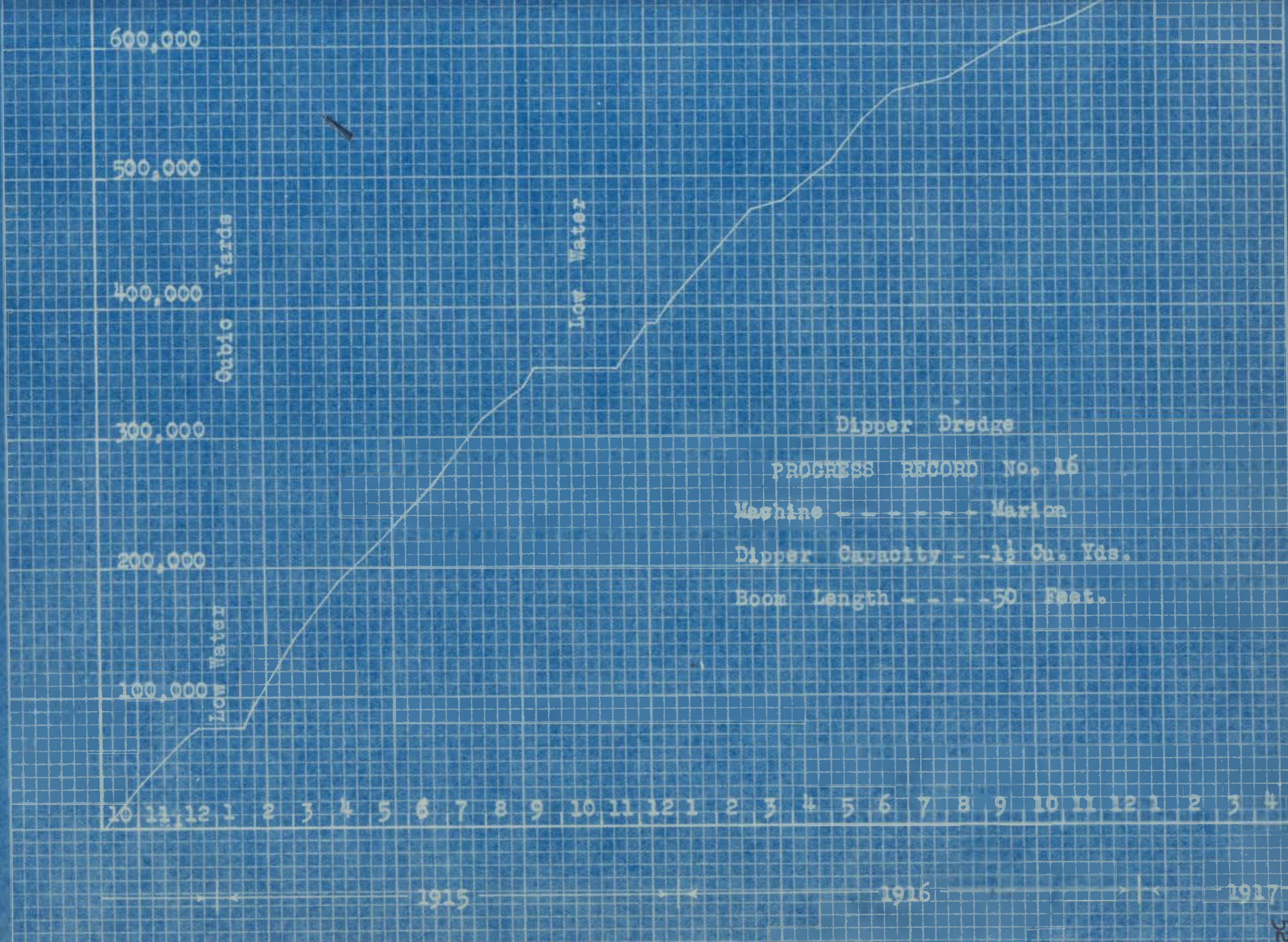


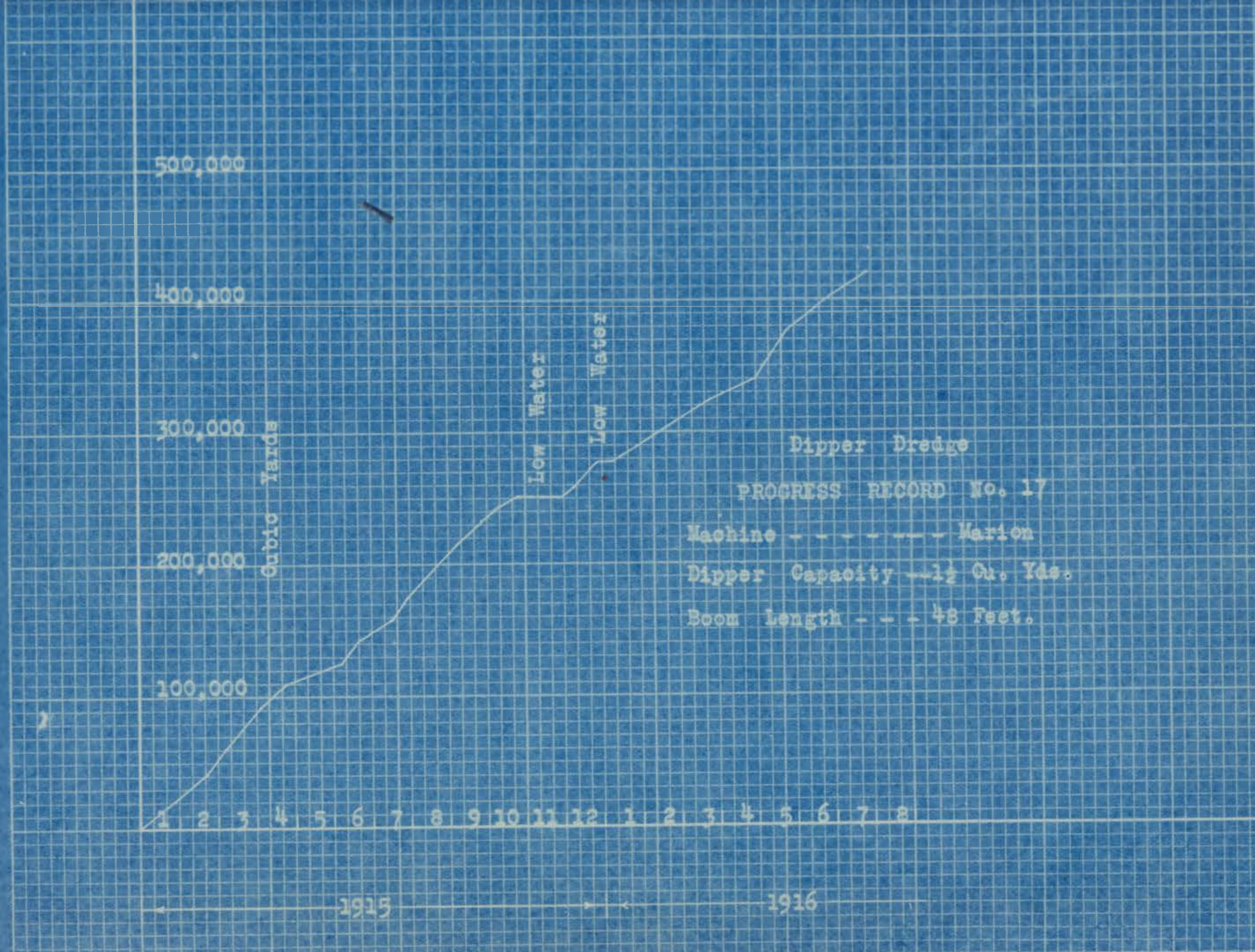


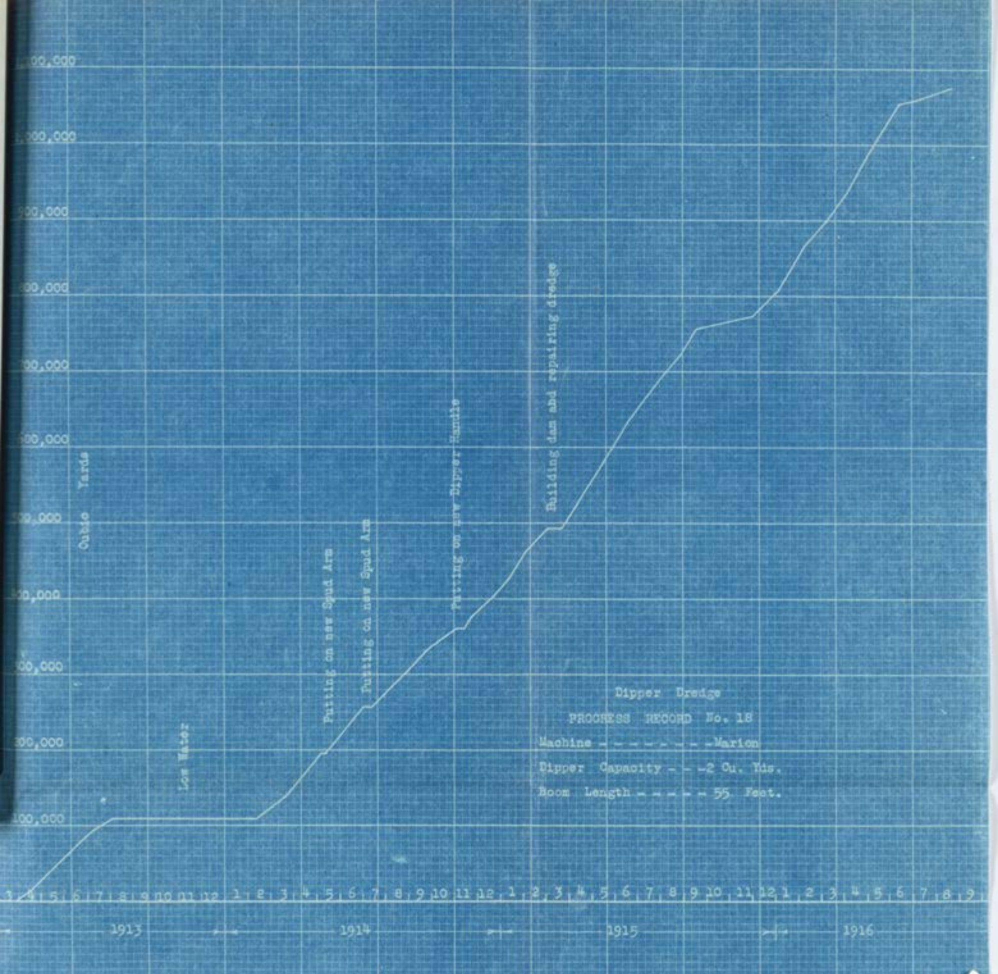
400,000
300,000
200,000
100,000
Cubic Yards
No Water
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10
1915
1916
Dipper Dredge
PROGRESS RECORD No. 14
Machine - - - - - - - - Marion
Dipper Capacity - - -1½ Cu. Yds.
Boom Length - - - - -50 Feet.

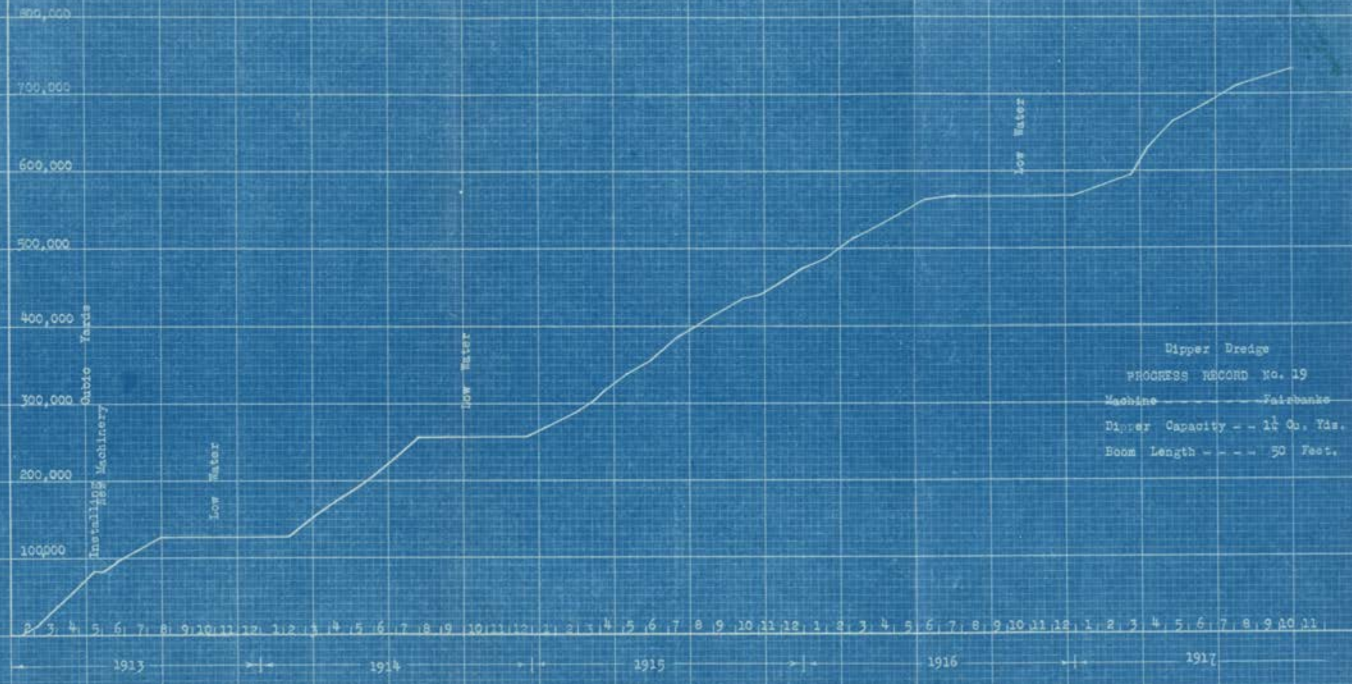


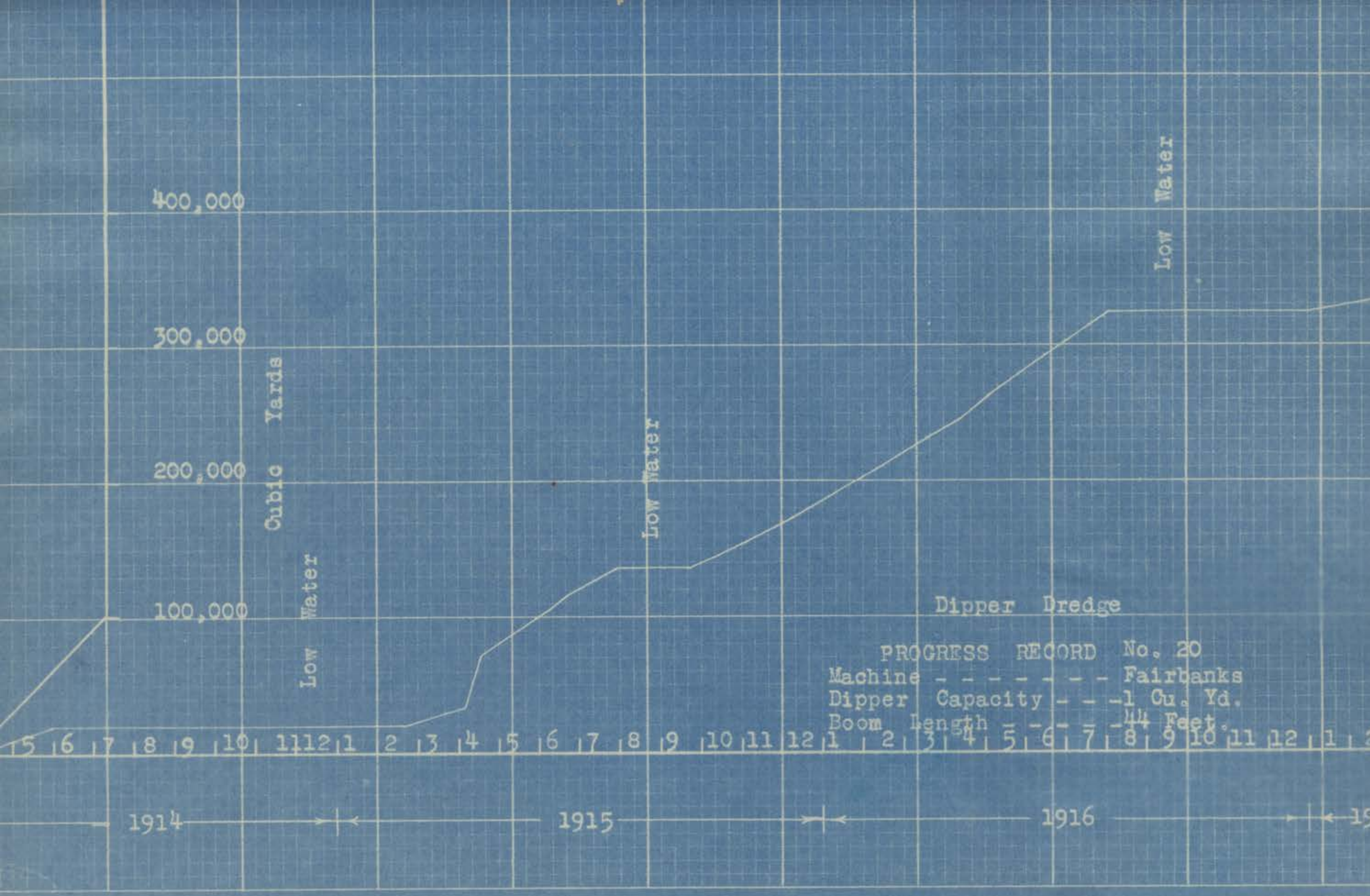
1,500,000
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
CUBIC YARDS
9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7
1914
1915
1916
Dipper Dredge
PROGRESS RECORD No. 15
Machine - - - - - - - - -Marion
Dipper Capacity - 3 Cu. Yds.
Boom Length - - - - 85 Feet.

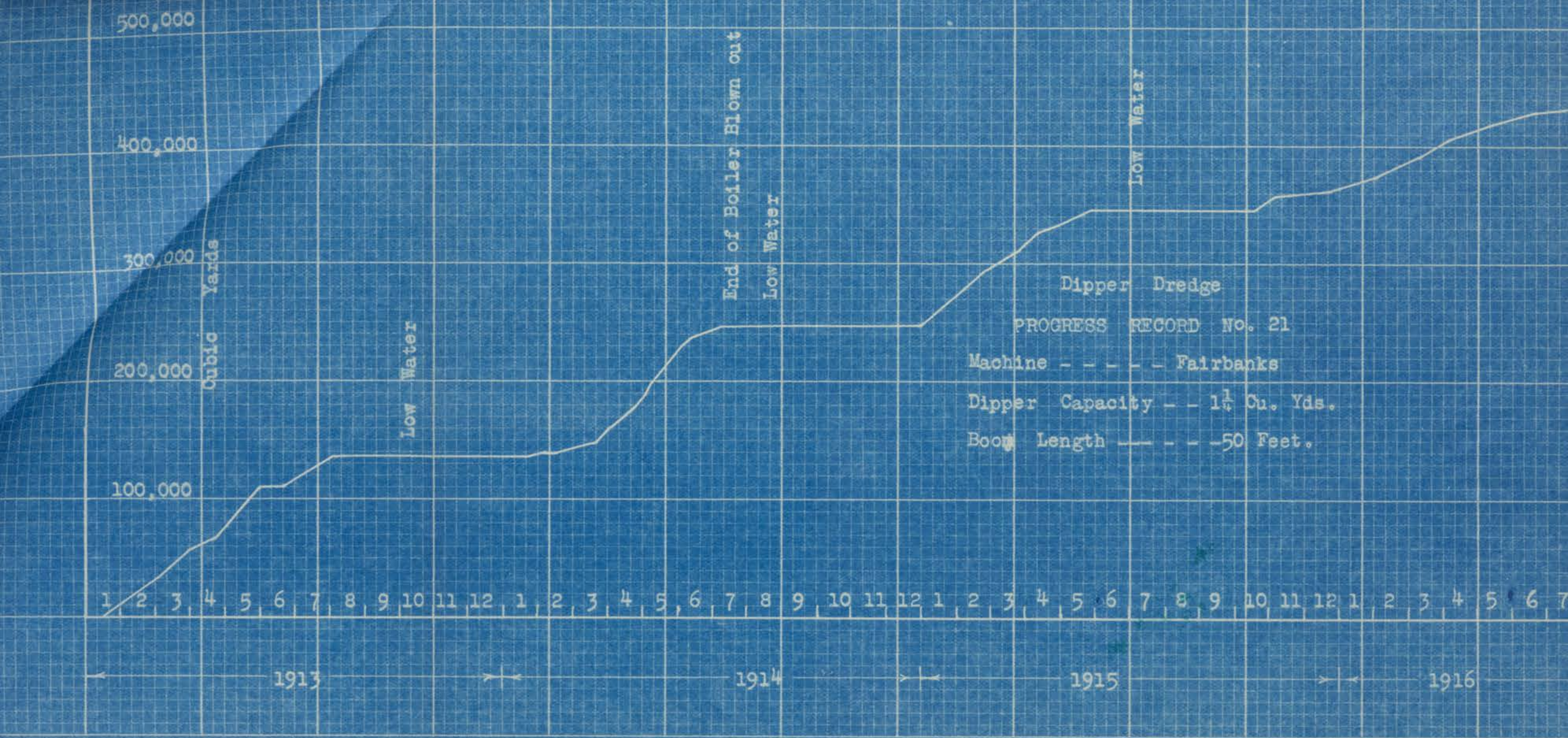

Dipper Dredge
PROGRESS RECORD No. 16
Machine - - - - - - - Marion
Dipper Capacity - -1½ Cu. Yds.
Boom Length - - - -50 Feet.
Cubic Yards
600,000
500,000
400,000
300,000
200,000
100,000
Low Water
Low Water
10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4
1915
1916
1917

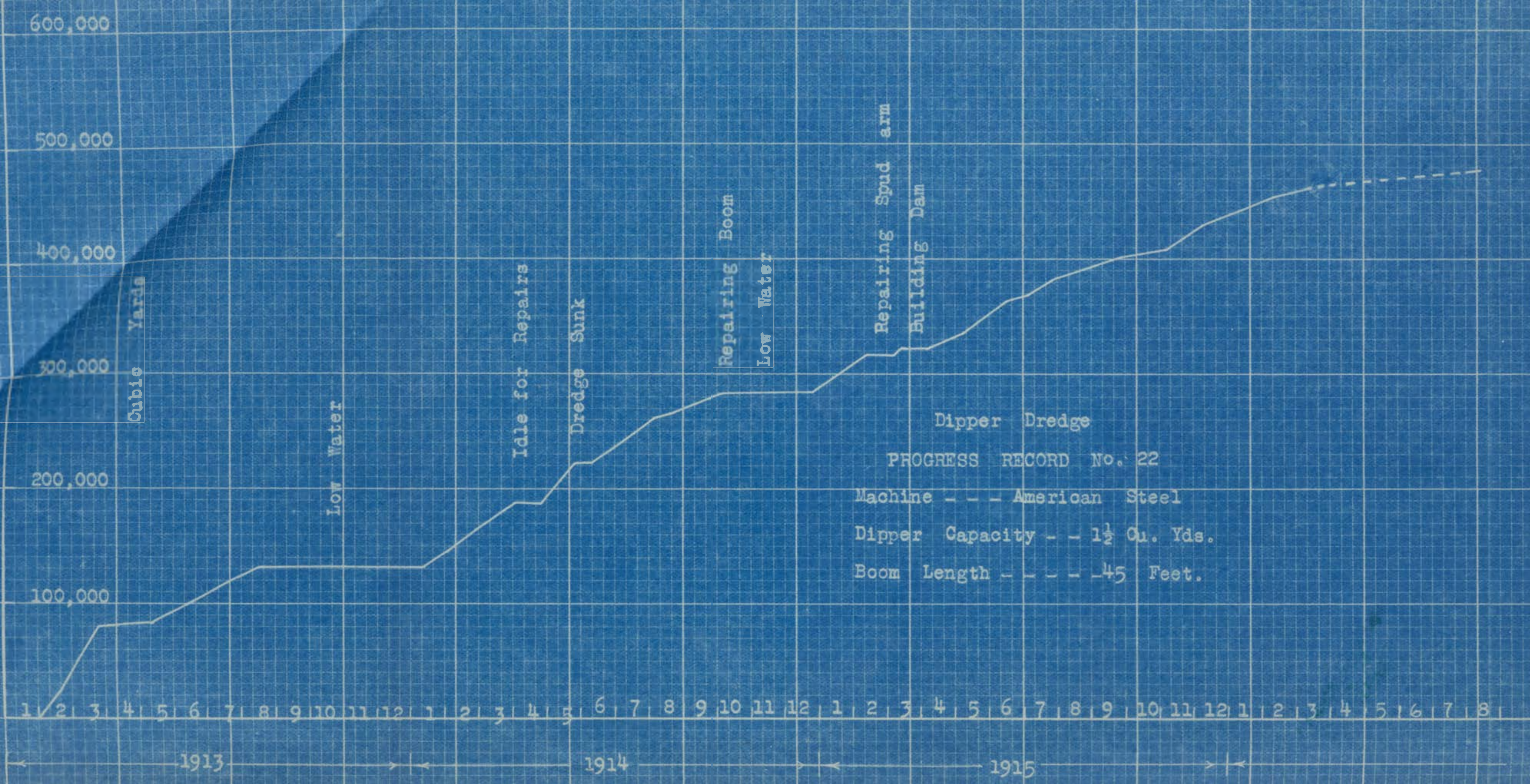

500,000
400,000
300,000
200,000
100,000
Cubic Yards
Low Water
Low Water
Dipper Dredge
PROGRESS RECORD No. 17
Machine - - - - - --- - Marion
Dipper Capacity --1½ Cu. Yds.
Boom Length - - - 48 Feet.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8
1915
1916

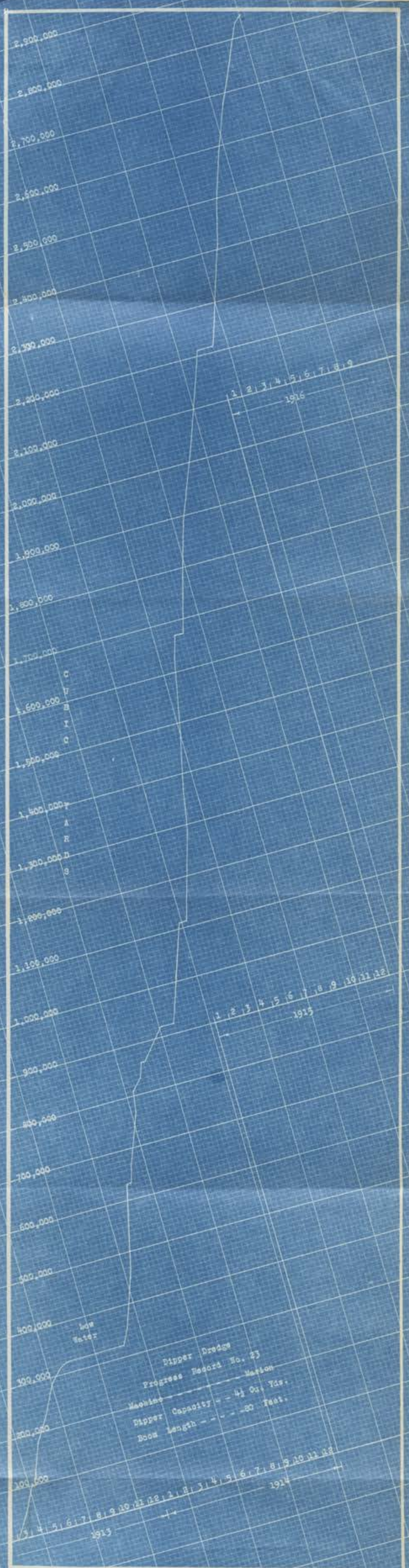

1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
Low Water
Putting on new Spud Arm
Putting on new Spud Arm
Putting on new Dipper Handle
Building dam and repairing dredge
Dipper Dredge
PROGRESS RECORD No. 18
Machine - - - - - - - - - Marion
Dipper Capacity - - -2 Cu. Yds.
Boom Length - - - - - - 55 Feet.
3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
1913
1914
1915
1916

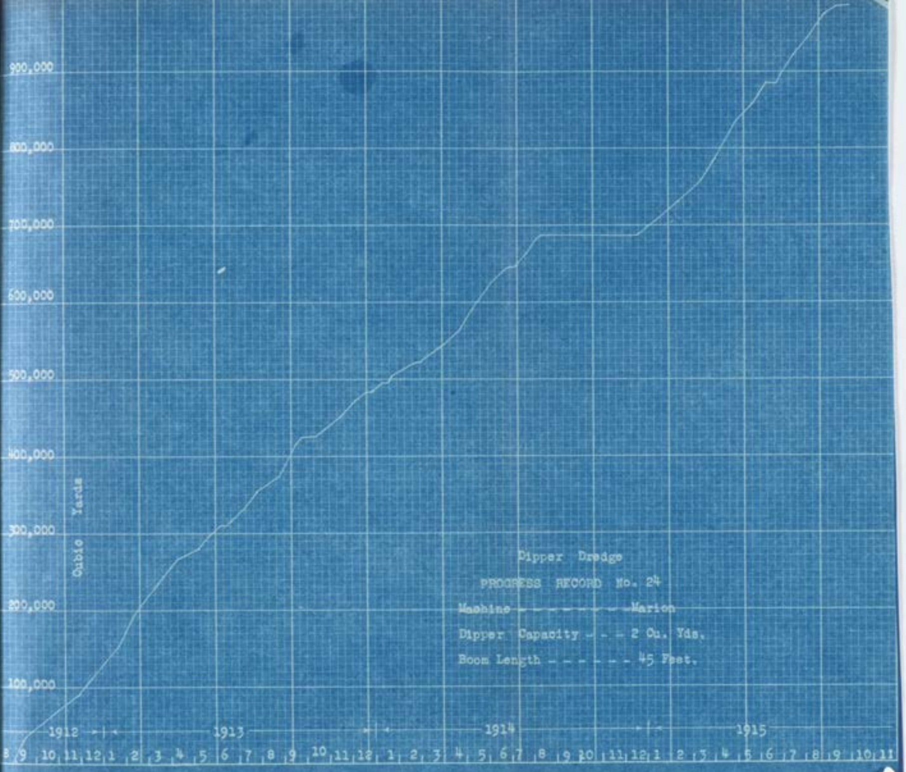

800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
Installing New Machinery
Low Water
Low Water
Low Water
1913
1914
1915
1916
1917
Dipper Dredge
PROGRESS RECORD No. 19
Machine - - - - - - - Fairbanks
Dipper Capacity - - 1¼ Cu. Yds.
Boom Length - - - - 50 Feet.


400,000
300,000
200,000
100,000
Cubic Yards
Low Water
Low Water
Low Water
Dipper Dredge
PROGRESS RECORD No. 20
Machine - - - - - - - - Fairbanks
Dipper Capacity - - - 1 Cu. Yd.
Boom Length - - - - - 44 Feet.
5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1
1914
1915
1916

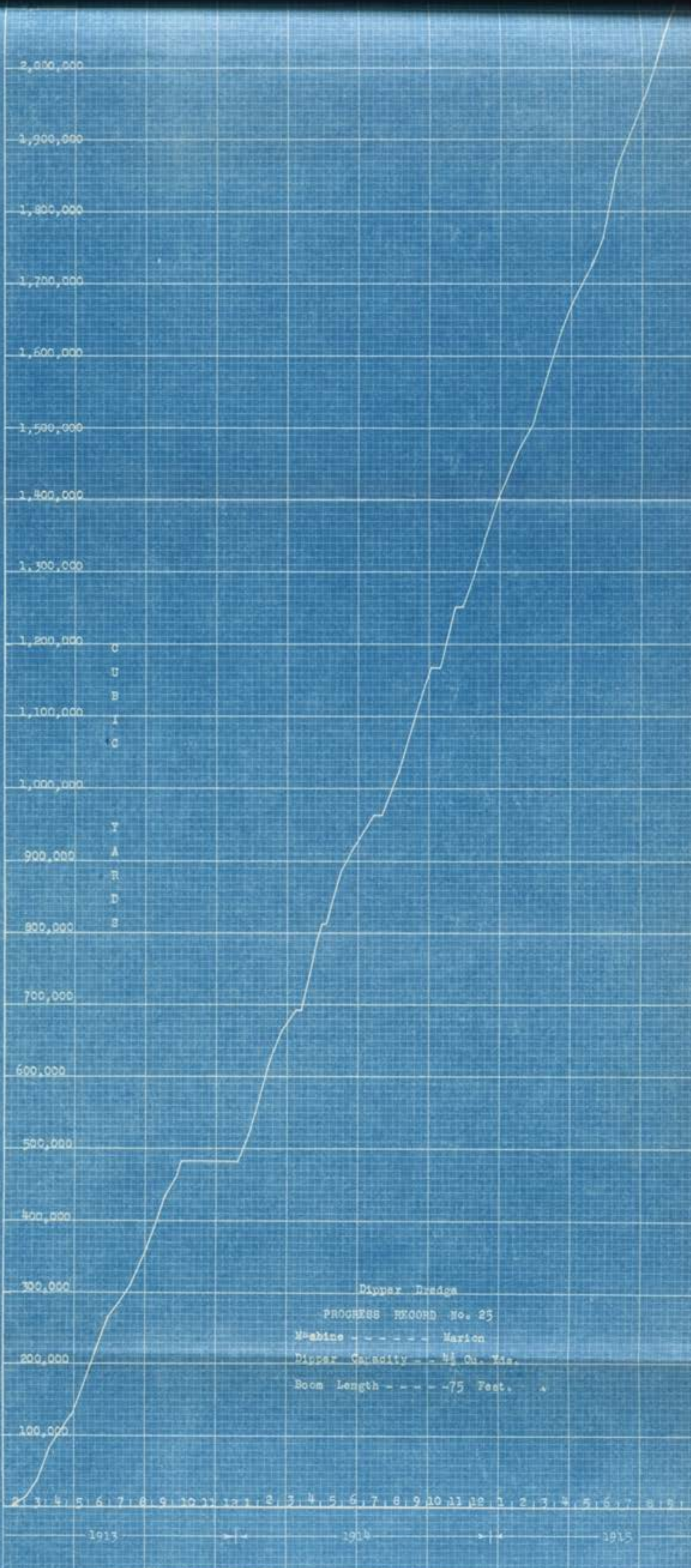

500,000
400,000
300,000
200,000
100,000
Cubic Yards
Low Water
End of Boiler Blown out
Low Water
Low Water
Dipper Dredge
PROGRESS RECORD No. 21
Machine - - - - - Fairbanks
Dipper Capacity - - 1¼ Cu. Yds.
Boom Length --- - - -50 Feet.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7
1913
1914
1915
1916

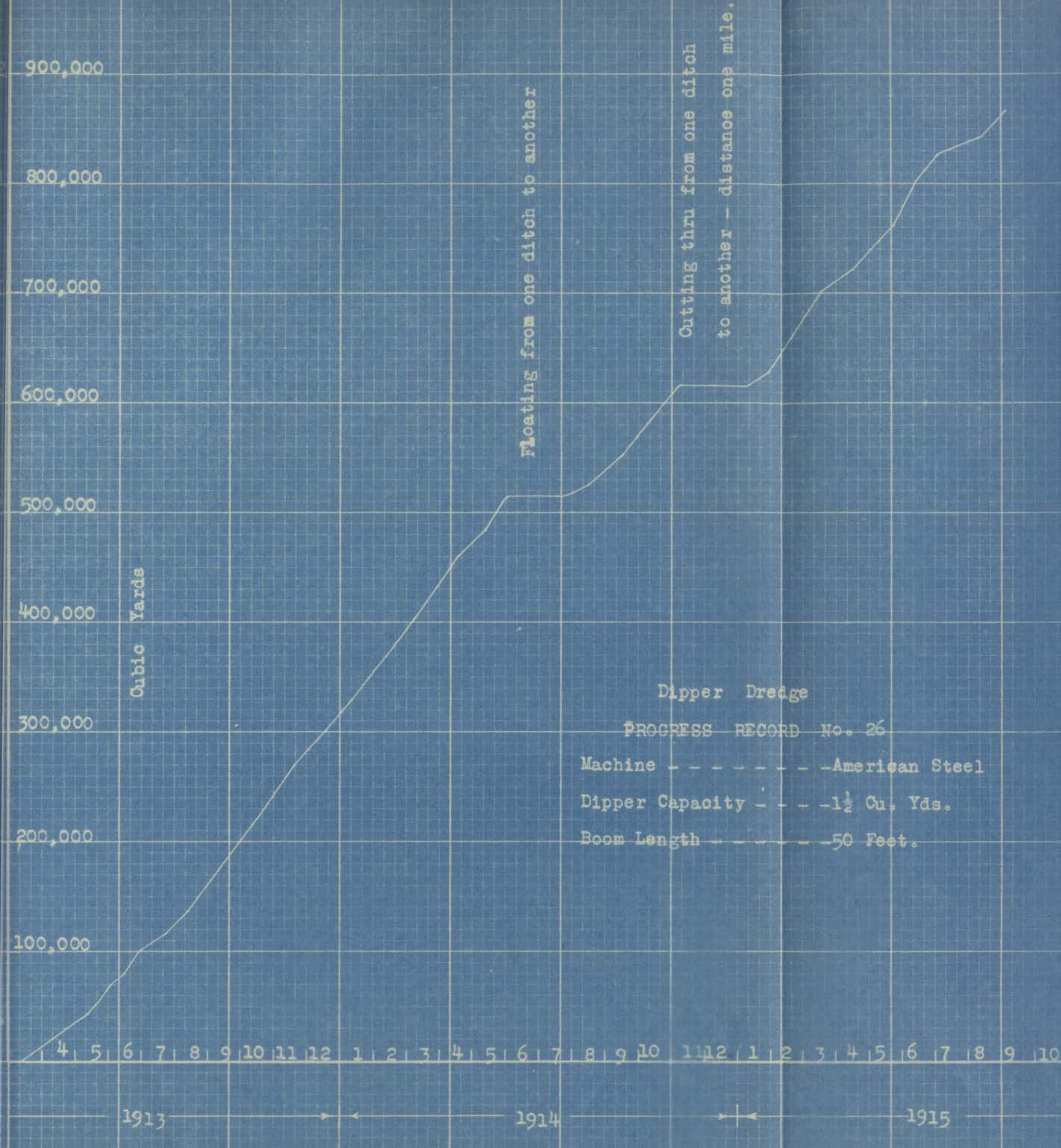

600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
Low Water
Idle for Repairs
Dredge Sunk
Repairing Boom
Low Water
Repairing Spud arm
Building Dam
Dipper Dredge
PROGRESS RECORD No. 22
Machine - - - American Steel
Dipper Capacity - - 1½ Cu. Yds.
Boom Length - - - - -45 Feet.
1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8
1913
1914
1915

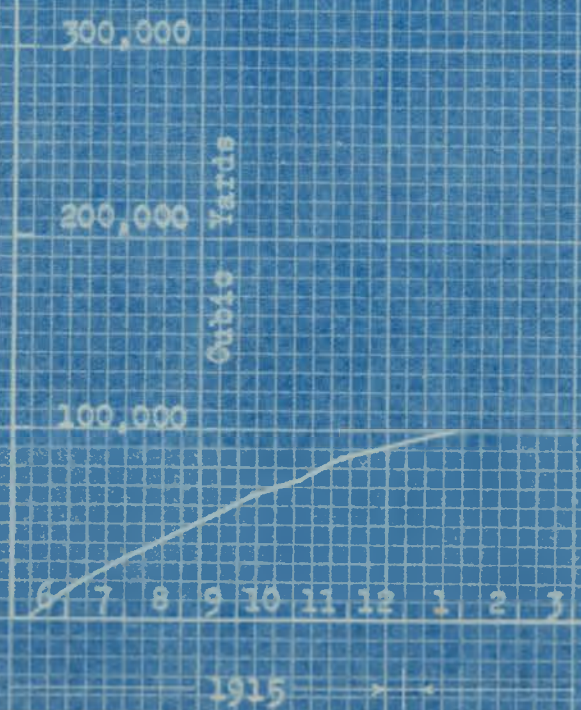

Dipper Dredge
Progress Record No. 23
Machine - - - - - - - Marion
Dipper Capacity - - 4½ Cu. Yds.
Boom Length - - - - 80 Feet.
Low Water
CUBIC YARDS
100,000
200,000
300,000
400,000
500,000
600,000
700,000
800,000
900,000
1,000,000
1,100,000
1,200,000
1,300,000
1,400,000
1,500,000
1,600,000
1,700,000
1,800,000
1,900,000
2,000,000
2,100,000
2,200,000
2,300,000
2,400,000
2,500,000
2,600,000
2,700,000
2,800,000
2,900,000
1913
1914
1915
1916



900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
Dipper Dredge
PROGRESS RECORD No. 24
Machine - - - - - - - - - Marion
Dipper Capacity - - - 2 Cu. Yds.
Boom Length - - - - - - - 45 Feet.
1912
1913
1914
1915
8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11


2,000,000
1,900,000
1,800,000
1,700,000
1,600,000
1,500,000
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
CUBIC YARDS
Dipper Dredge
PROGRESS RECORD No. 25
Machine - - - - - - Marion
Dipper Capacity - - 4½ Cu. Yds.
Boom Length - - - - -75 Feet.
2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9
1913
1914
1915


900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
Floating from one ditch to another
Cutting thru from one ditch
to another - distance one mile.
Dipper Dredge
PROGRESS RECORD No. 26
Machine - - - - - - - - -American Steel
Dipper Capacity - - - -1½ Cu. Yds.
Boom Length - - - - - - -50 Feet.
4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10
1913
1914
1915



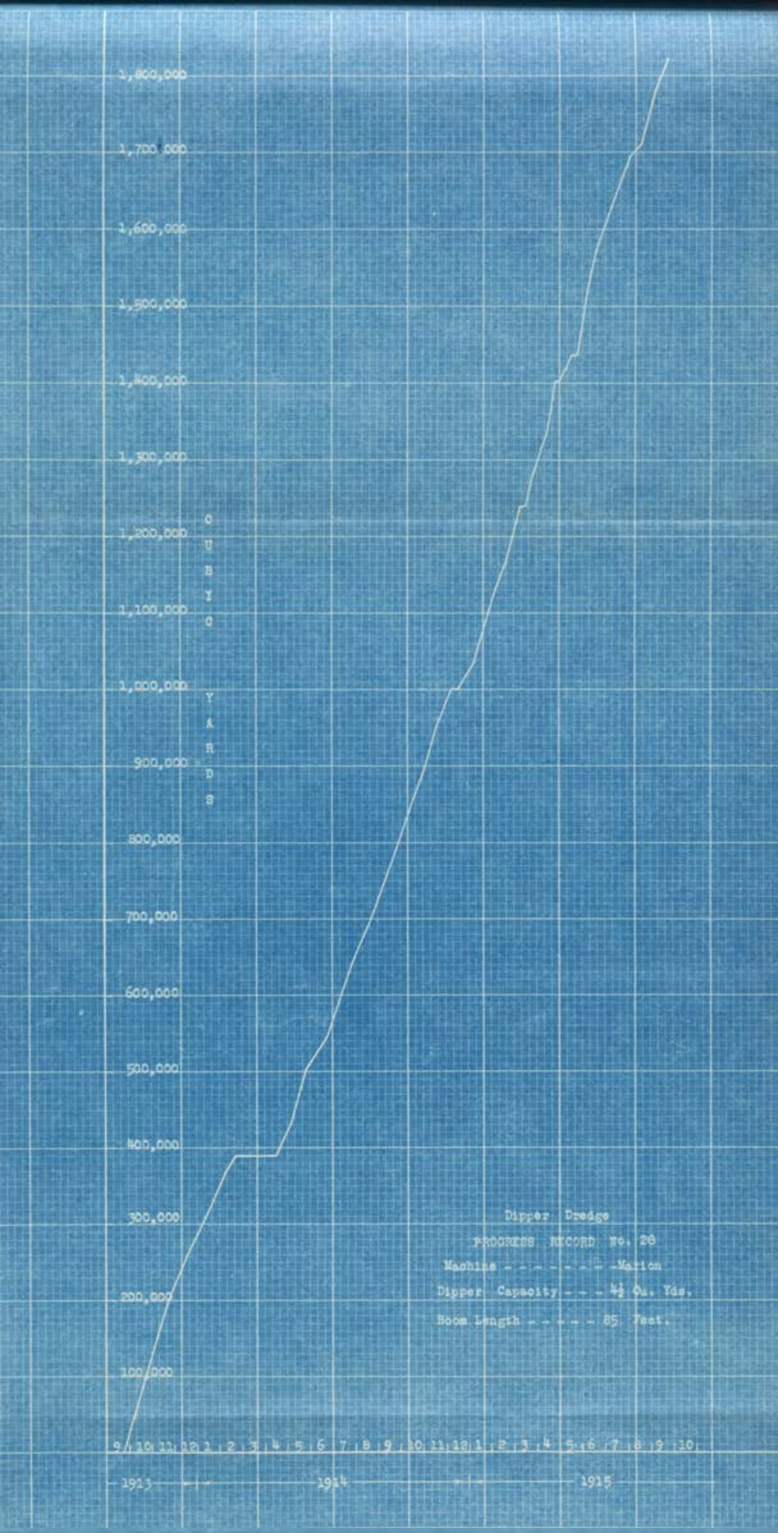
Dipper Dredge

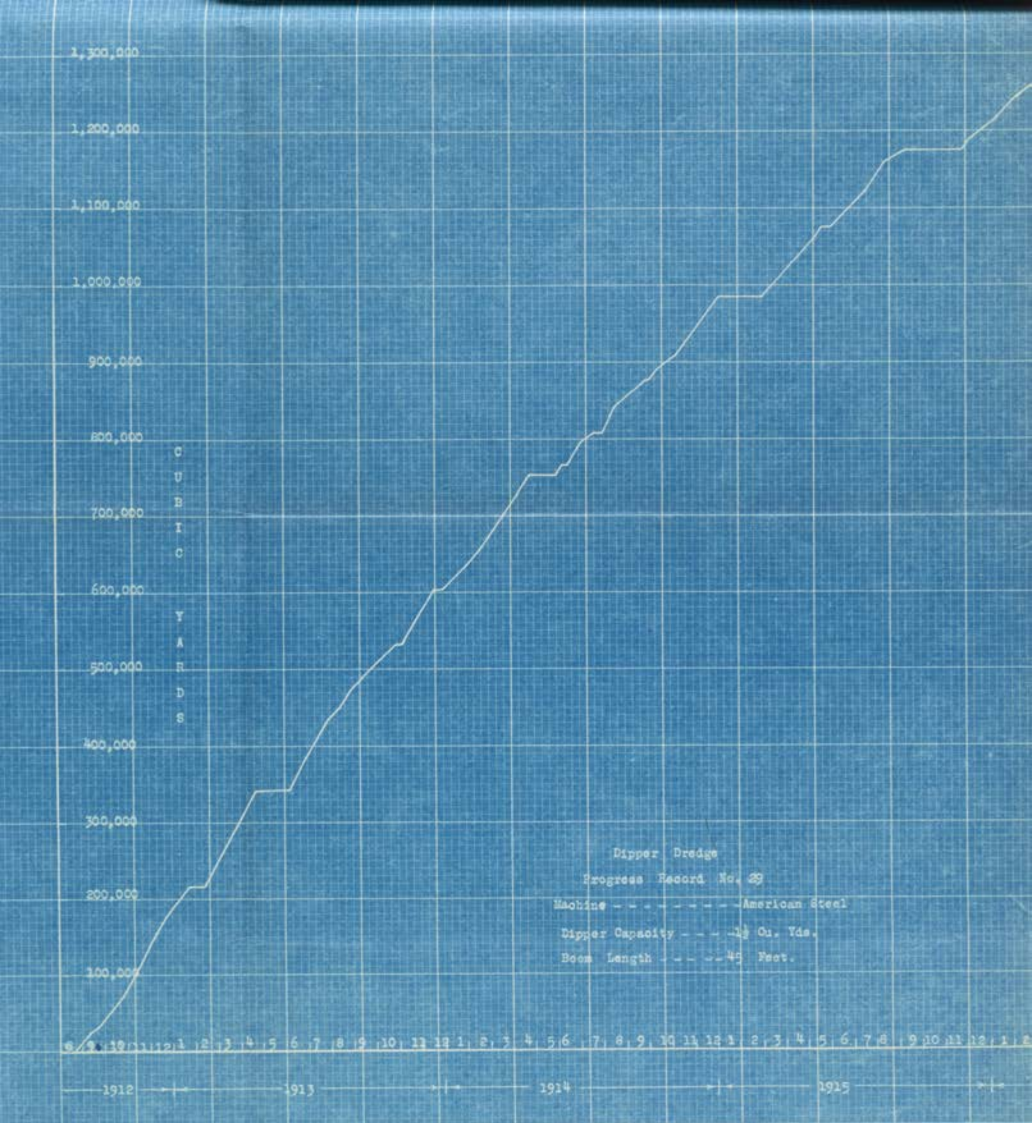
PROGRESS RECORD No. 27

Machine - - - - - - Marion

Dipper Capacity - - 1¼ Cu. Yds.

Boom Length - - - - 52 Feet.


1,800,000
1,700,000
1,600,000
1,500,000
1,400,000
1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
CUBIC YARDS
9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10
1913
1914
1915
Dipper Dredge
PROGRESS RECORD No. 28
Machine - - - - - - - - -Marion
Dipper Capacity - - - 4½ Cu. Yds.
Boom Length - - - - - 85 Feet.


1,300,000
1,200,000
1,100,000
1,000,000
900,000
800,000
700,000
600,000
500,000
400,000
300,000
200,000
100,000
CUBIC YARDS
1912
1913
1914
1915
Dipper Dredge
Progress Record No. 29
Machine - - - - - - - - - American Steel
Dipper Capacity - - - - 1½ Cu. Yds.
Boom Length - - - - - 45 Feet.

Costs.- The amount of material to be moved by one machine is one of the chief factors entering into the cost of dredge operation. The initial cost of installing a dipper dredge on any job is quite high and unless a contract contains at least 350,000 or more cubic yards, the cost per yard for installation will be large and the total price per yard will necessarily be higher than would be the case on a larger contract. The size of channels which likewise determines the size of machine to be used is an influence on the cost. The grade line of a channel plays a part also for if the work is dug uphill or upstream as is quite often the case, steep grades require many dams to hold up the water level so the boat can operate and such dams, altho temporary, are expensive and troublesome. Local conditions regarding availability of fuel supply may cause variance in the cost of similar work in different localities. Superintendence plays a vital part in the actual cost to the contractor and indirectly to the parties contracting the work to be done for contractors with the best superintendents can do work most efficiently and hence at less cost.

During the years immediately preceding the European War the cost of dipper dredge work varied between about 5 and 10 cents with a general average price somewhere close to 8 cents prevailing. These prices are for work in flat wooded country and work in hill valleys cost a few cents more on the average.

The table on the next page gives the costs of a large volumeof dipper dredge excavation performed or now under contract in the South.

COST OF DRAINAGE EXCAVATION IN SOUTH BY DIPPER DREDGES

Note.- The location of the work, size of contract, and dimensions of the ditches excavated may be found by referring to the Table Of Information To Accompany Dipper Dredge Progress Records. For convenience of reference, the Progress Record No. is here given.

Progress Record No.	Contract Price Per Cubic Yard --Cents--	Remarks
1	7.85	
2	7.85	
3	7.46	
4	7.46	
5	10.00	Work consisted of building levees. Preparation of levee base included in price.
6	10.00 and 9.9	" " " " " " " "
7	8.5	
8	8.5	
9	10.0	Depth of ditch caused high cost.
10	8.5	
11	8.5	
12	8.5	
13	8.5	
14	8.5	
15	9.5	Cost high due to large size of channel.
16	8.5	
17	8.5	
18	7.9	
19	7.9	
20	7.9	
21	6.99	
22	9.0	
23	5.93 and 5.7	Low costs due to large yardage.
24	8.0	
25	6.35	Low cost due to large yardage.
26	7.45	
27	11.25	High cost due to small yardage.
28	6.3	Low cost due to large yardage.
29	7.0	Low cost due to large yardage.

2.Dipper Dredge

b-Land

Description.- The land dredge is essentially a small dipper dredge ,the machinery being mounted on a structural steel frame which straddles a ditch upon which excavation is being done. The frame is fitted with front and rear axles upon which are wheels which move along the bank of the ditch. The booms of these dredges are steel latticed channels. The dippers are made of steel . Power is furnished by oil burning engines ordinarily of 25 Or 30 horse-power.

Dry Land Dredge In Operation

Land dredges are made with dippers from 1/2 to 1½ cubic yards capacity and with booms up to 50 feet in length. The span of the machine varies from 14 to 50 feet so that these land dredges can dig in ditches with top widths from 10 to 45 feet. Equipped with a long dipper handle and boom,depths of 12 to 15 feet can be reached altho such depths are not the economical ones for the machine.

The track upon which runs the wheels supporting the frame and machinery is made up of short sections of tee rail which are shifted as required to keep a track in front of the dredge. Some machines have caterpillar traction motion instead of wheels and track.

The land dredge is designed so that it can be readily dismantled and moved from place to place without great difficulty, expense, or loss of time. One of these excavators can be taken down, hauled several miles, and set up again in a week's time.

Uses.- Land dredges are used for digging small ditches up to 40 or 45 feet wide on top and are employed to a limited extent in throwing up levees and dikes. In open country with few stumps, the land dredge is at its best. It can in no sense be thot of as a competitor of the floating dredge for it lacks the tremendous power of uprooting heavy stumps that the latter possesses. For work comprising several disconnected ditches,the land dredge is well adapted since it is readily moved from ditch to ditch.

There are many practical difficulties which occur in the operation of a land dredge. Unless the ground is very firm,trouble is likely to result from caving of the ditch banks caused by the weight of the machine. The track upon which the dredge runs offers other objections. In the first place, the ground must be fairly level and smooth for the track to be laid upon. When the berms of the ditch become softened and muddy, it is difficult to handle the track . The track sinks in the mud from the weight of the machine and sometimes jacks are required to pry the track out of the mud. Where caterpillar traction is used, these track troubles are avoided.

Performance and Costs.- On the following page will be found a table showing the information relative to the operation of the two leading makes of land dredges. Examination of the data in this table shows that from 5000 to 15,000 cubic yards of material can be excavated in a month by a land dredge. The unit costs given, it must be remembered, are for the period prior to the European War and for present conditions would cost at least 25 per cent more.

3. Walking Dredge

Description.- The walking dredge, like the land dredge, is a machine which straddles the ditch. The distinguishing feature of this type of dredge is its method of locomotion. The frame of the machine is constructed of large sized wooden members. On each corner of the frame is a timber foot built up to a width of about 6 feet and a length of about 8 feet. In the center of each side is another foot similar to the corner feet but nearly twice as long. The details of the dredge are so arranged that the machine raises itself from the corner feet and the weight is brot to bear on the center feet. The whole machine then slides forward about 6 feet , the center feet remaining stationary. The corner feet are then lowered, the center feet are raised, and pulled forward again

PERFORMANCE AND COSTS OF LAND DIPPER DREDGES

No.	Location	Size of Contract	Contract Price per Cu.Yd.	Dimensions of Work: Bottom Width	Dimensions of Work: Average Cut	Capacity	Soil
		Cu.Yds.	Cents	Ft.	Ft.	Cu.Yds.	
1	Indiana	50,000	22	3 - 4	8.5	250 to 450 per 10 hrs.	Clay and hardpan
2	Indiana	25,000	12	6 - 8	6.5		Hardpan and loam
3	Indiana	45,000	20	3	10.0		Hardpan and gravel
4	Michigan	31,000	5.3				
5	Florida	42,000	22	5 - 30	3.5	7,500 per month	Rock, clay, sand, muck
6	Louisiana	71,000	10¼	6 - 14	5.0	5,000 to 10,000 per month	Red gumbo
7	Ohio	35,000	20	3 - 4	8.0	15,000 per month	Clay
8	Michigan		15	20	6.0	700 per day	Hard clay
9	Michigan			4 - 8	5 - 9	500 to 900 per day	Loam and clay
10	Minnesota		4 to 6 (actual cost)	6	7.0	1,200 per day in two shifts	Muskeg, clay roots, stumps

NOTE.- Nos. 1 to 4 inclusive are for Wickes Bros. dry land dredges. Nos. 5 to 10 inclusive are for Bay City land dredges.

ready for another move.

The boom is in two sections, an upper ahd a lower. The upper section is hung from an A-frame in much the same manner as the boom of a dipper dredge, and maintains a fixed angle with the horizontal during operation. The lower section is pivoted to move in a vertical plane, the upper section being also in the same plane. The lower section is raised and lowered by a cable passing over the

Walking Dredge Excavating Drainage Canal

point of the upper section. The dipper, which closely resembles a scraper pan, is attached to a handle which pivots about its center from the extreme outer end of the lower section. The process of excavation consists in lowering the lower section of the boom until the dipper is in the digging position. The top end of the dipper handle is then pulled back which forces the dipper forward and into the material. When the dipper is loaded, the lower section of boom is raised, the entire boom is swung to the side, and the bucket dumped.

The boiler and engines of the walking dredge are similar to the equipment used on floaters, modification being made to the extant necessary to provide the power for moving the dredge Oil engines have been used on these dredges where coal was difficult and costly to obtain.

The walking dredge was invented by a man named Cross and it is commonly known as the Cross machine.

Use.- The principal use of walking dredges lies in constructing small sized ditches and embankments. In large drainage districts, the upper ends of the later ditches need not be nearly so large as the minimum sized floating dredge ditch but in many cases it has been found cheaper to construct the oversized ditches with a floater than to dig smaller ditches by other means. The walking dredge is well adapted to constructing such upper ends of laterals and since it can dig a much smaller ditch than the floating machine, and since the size of ditch it can dig is ample to provide drainage, the walker can do the work as cheap per mile as the floater.

The walking device makes it possible for the dredge to move itself across country under its own power without dismantling Thus when the upper end of one lateral of a large drainage district is completed, the walker moves overland to the next ditch.

The Cross machine is never delayed by lack of water. In fact, a dry ditch is preferred for this makes firmer banks and enables the operator to see his work. With all of the ditch in view it is much easier to dig a good ditch than it is with a floating dredge where practically all the excavation is performed under water.

The walker is at a decided disadvantage in handling large stumps and the path of the ditch must be cleared thoroly by blasting in advance of the excavation. This is an important item in the cost of excavation by walking dredges in the heavily timbered regions of the South.

Performance.- Under good working conditions, a Cross machine can be relied upon to excavate from 30,000 to 50,000 cubic yards of earth per mpnth.

Costs.- The cost of excavation by walking dredges is perhaps 20 per cent higher than by dipper dredges. As previously explained, however, the upper ends of lateral ditches may be excavated as cheaply or cheaper by the walker as by the floater because the former need only excavate a ditch of sufficient size to afford good drainage whereas the latter would have to dig an overly large ditch.

4. Drag Boat

Description.- The drag boat or "King's Ditcher" consists of a trapezoidal hull the bottom of which rests on the bottom of the ditch and the sides of which parallel or are in contact with the sides of the excavation. On the hull is placed the machinery which is similar in character to that used on the dipper dredge. In moving, the hull is dragged forward by means of a cable and dead men set ahead of the digging. These machines are made in small sizes only for large machines would be too heavy to drag along the ditch. The boom lengths range from 25 to 30 feet and the dipper capacities from $\frac{1}{2}$ to $\frac{3}{4}$ cubic yards.

Uses.- The "King's Ditcher" is adapted to excavating small sized ditches with 4 to 6 feet width of bottom. It has been successful in material that would stand without caving and wedging the bottom of the machine. Altho designed primarily for dry excavation, the drag boat can be used in several feet of water.

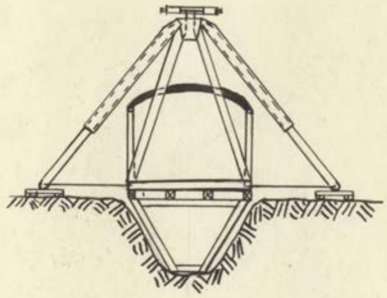


Diagram of Drag Boat

Performance.- The manufacturers guarantee a capacity of from 300 to 600 cubic yards per day for a $\frac{3}{4}$ yard bucket and about a third less for a $\frac{1}{2}$ yard bucket.

B.-SUSPENDED CABLE MACHINES

1.Drag Line

a-Mounted on Tracks, Rollers, or Wheels

Description.- The drag line excavator is in many ways the most highly developed type of equipment in use for ditch excavation. The ordinary drag line machine has two platforms built up of structural steel shapes. The lower platform is stationary and is mounted either on wide traction wheels, skids and rollers or on car wheels or swiveling trucks.

The traction wheels and skids and rollers run on plank-ways laid along in front of the machine. Car wheels or trucks travel on a moveable track made up of short sections of railroad rails.

The upper platform which carries all the machinery is mounted on heavy cast steel wheels which rotate on a heavy rail circle riveted to the lower platform. The boom consists of two latticed steel girders spread at the bottom to about three fourths of the width of the upper platform and converging together at the upper end. The boom is hung from a steel A-frame attached to the upper platform.

Drag Line Excavator

From the point of the boom the bucket is suspended by cables passing over a pulley on the end of the boom. The chief distinguishing feature which separates the drag line from the dipper dredge is that the bucket hangs from the boom on a cable but has no handle attached to it. Instead, a drag line passes from the bucket to the engines over a pulley at the foot of the boom and it is by lowering the bucket into the material in a digging position and then pulling on the drag line that the excavator does its work.

Drag lines may be either steam, gasoline or electrical

Drag Line Excavators Digging Large Canal

drive. A main engine is required to control the bucket and a swinging engine is necessary to rotate the machine. Where steam power is used, locomotive type of boilers are used for the most part.

In operation the bucket is filled in the manner described above. The bucket must be heavy enough so that it will dig when the drag line is pulled taut. After the bucket is filled, the swinging engines start revolving the whole machine and the main engines at the same time raise the bucket and pull it out towards the end of the boom. When the bucket is at the right point, it is tripped, the swinging engine reversed, and the whole process repeated. The machine may either follow down the centerline of the excavation backing away from the completed work or may travel down one side of the channel. The first method is followed in small ditches, the second in large channels in which case it is not uncommon for the machine to travel down one side and back the other.

Small Drag Line Machine Digging Plantation Ditch

Drag line machines are made with booms from 40 to 150 feet long and with buckets holding from 1 to 5 cubic yards. Only a comparatively few machines have been manufactured with booms over 100 feet long.

Uses.- The drag line machine is particularly fitted by its wide radius of action to the excavation of very large channels which cannot be dug with floating dipper dredges. The cost of drag line work is higher than dipper dredge work and for this reason it is more economical to dig all ditches that can be so constructed with the latter type of machine. On particularly large ditches or in making high embankments which are beyond the limit of dredge operation, the drag line finds its best field in drainage work.

In digging channels with a drag line, the slopes of the sides can be cut almost exactly to any desired slopes which is a thing unattainable with the dipper dredge. Wider berms may be left by a drag line than by a dredge of the floating kind because of the method of operation and because of the long booms carried by drag line machines.

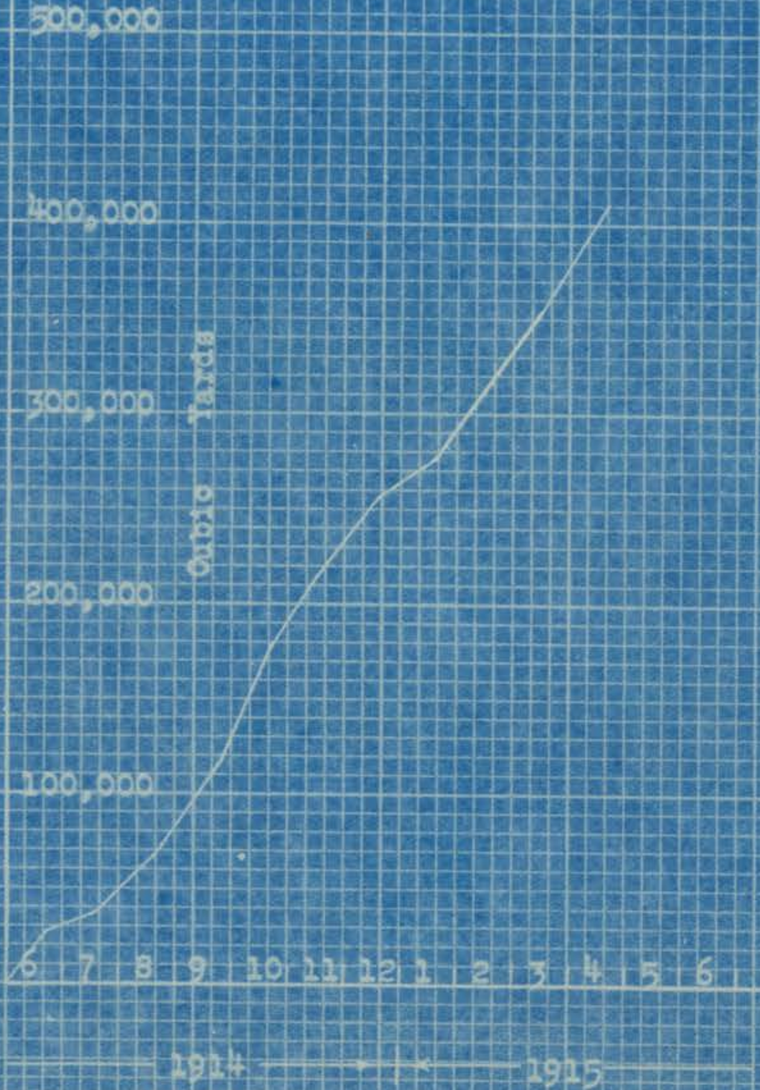
Performance.- Drag line excavators can dig under water but do not require water so that no delays are experienced due to lack of water. Breakdowns, repairs, and management are the principal factors in the progress of drag line work under a given set of natural conditions.

On the next few pages are some progress records for actual operations of drag lines. The accompanying table explains the most important of the conditions surrounding the work. It will be noted that these records are more uniform than the records of floating dredge progress. Drag line work usually attracts a higher class of men than dredge work which is done by a much lower grade of men.

In specifying drag line progress, the conditions of the work must be considered. The rate should be less in proportion to the bucket capacity and boom length than for dredge work. A rate from 20,000 to 40,000 cubic yards per month is ordinarily a reasonable one to require.

TABLE OF INFORMATION
TO ACOMPANY
DRAG LINE PROGRESS RECORDS

Progress Record No.	Location of Work	Total Excavation Paid For	Dimensions of Work	
			Bottom Width	Average Depth
		Cu. Yds.	Ft.	Ft.
1	Central Miss.	411,000	80 - 120	17.0
2	Central Miss.	716,000	80 - 120	17.0
3	Eastern Arkansas	498,000	38 - 44	13.0



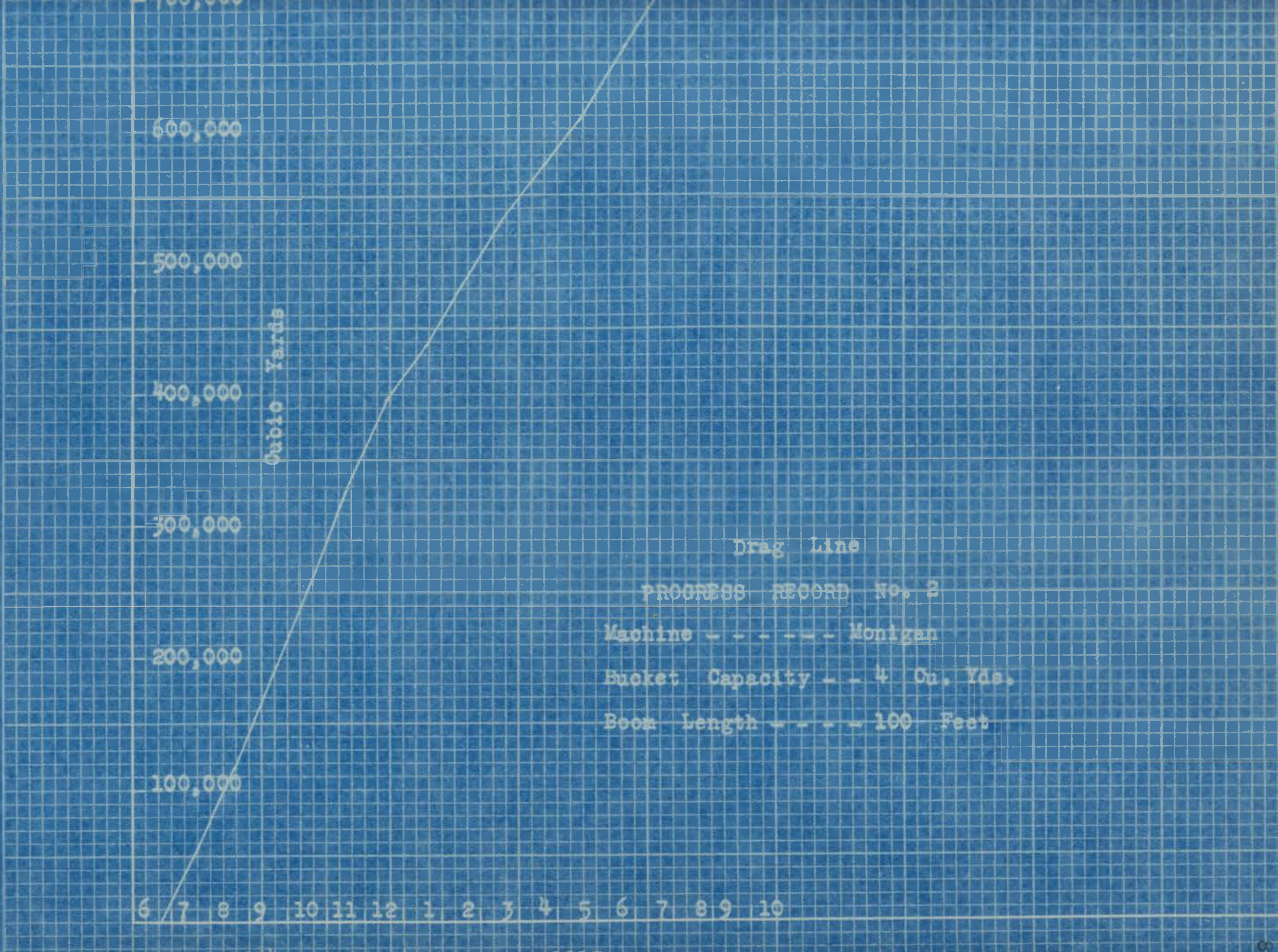
Drag Line

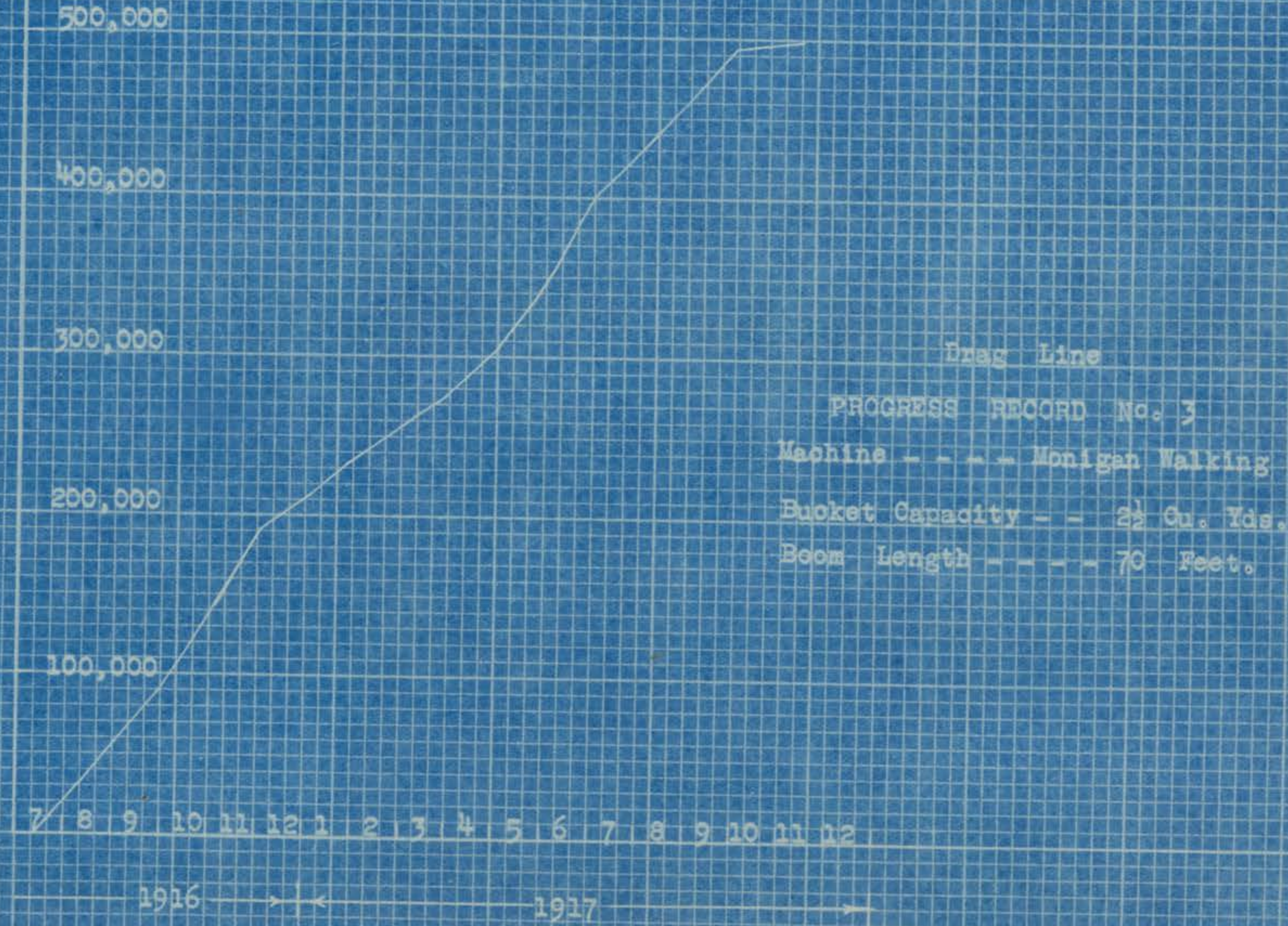
PROGRESS RECORD No. 1

Machine - - - - - - - Monigan

Bucket Capacity - - - - $2\frac{1}{2}$ Cu. Yds.

Boom Length - - - - - - 85 Feet.


600,000
500,000
400,000
300,000
200,000
100,000
Cubic Yards
6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10
Drag Line
PROGRESS RECORD No. 2
Machine - - - - - - Monigan
Bucket Capacity - - 4 Cu. Yds.
Boom Length - - - - 100 Feet



500,000
400,000
300,000
200,000
100,000
7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12
1916
1917
Drag Line
PROGRESS RECORD No. 3
Machine - - - - Monigan Walking
Bucket Capacity - - 2½ Cu. Yds.
Boom Length - - - - 70 Feet.

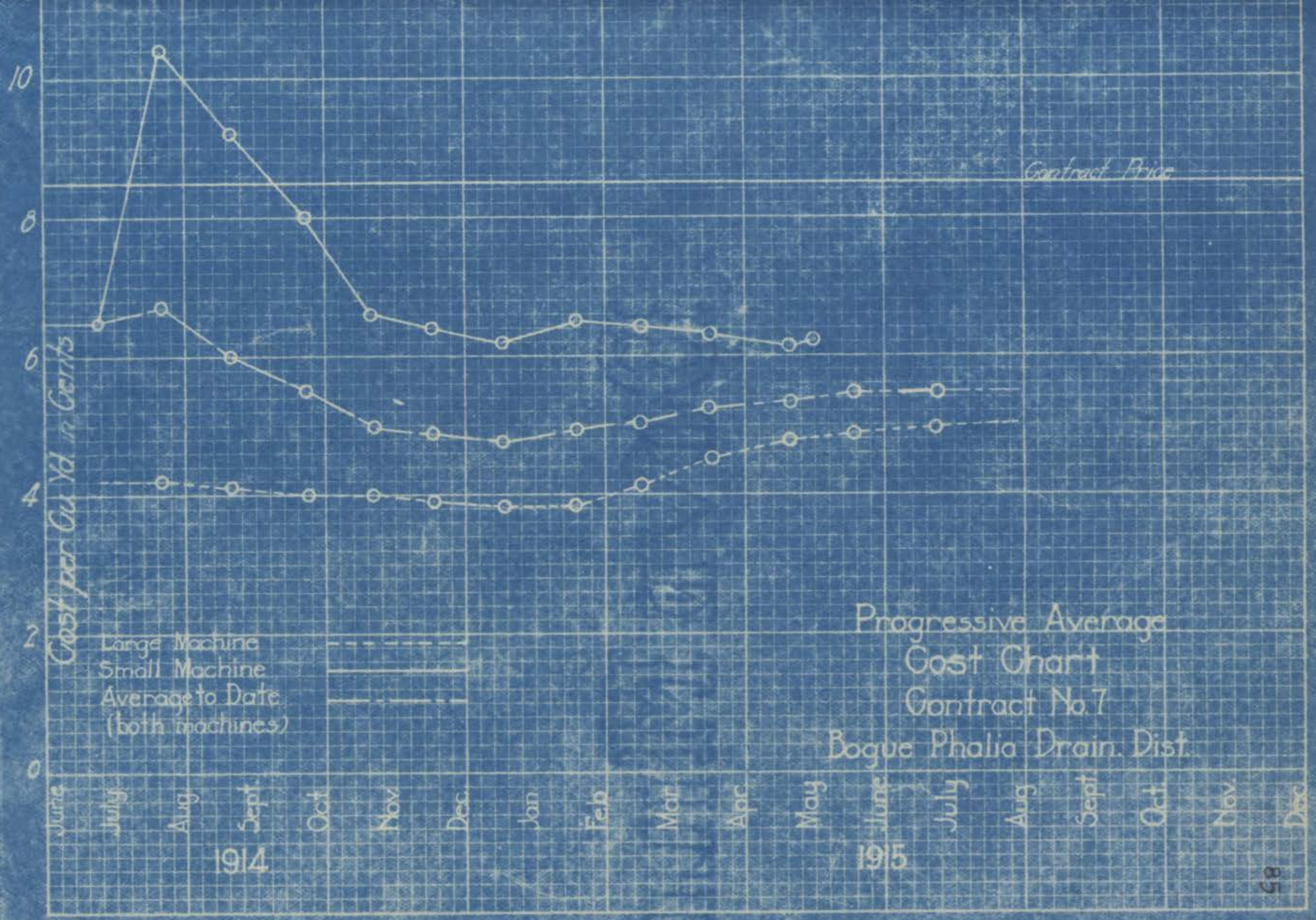
Costs.- An accurate record was kept of the cost of operation of two draglines in the Bogue Phalia Drainage District of Washington County, Mississippi. On the next succeding pages are cost charts showing how the cost of the work varied over the period of operation and also showing the average costs during and at the end of the work. The machine noted as the large machine had a boom 100 feet long and carried a 4 yard bucket. The small machine had an 80 foot boom and a 3 yard bucket.It must be borne in mind that the cost shown are for operation only and include no overhead, depreciation, or similar items.

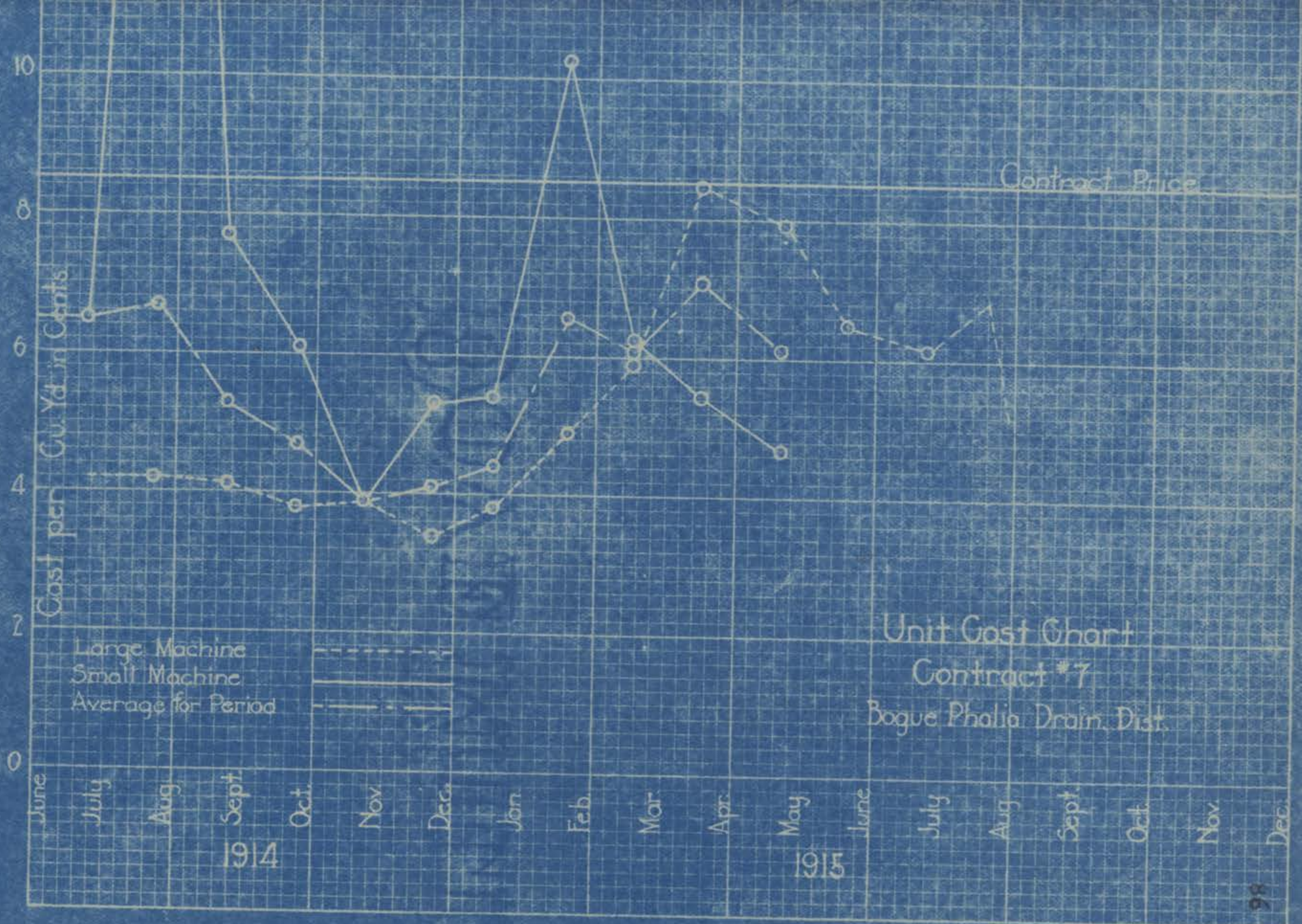
A few years ago in the days before the European War, drag line prices in general ranged from 12 to 20 cents per yard. At this writing prices have risen at least a fourth greater.

1.Drag Line

b-Walking

Description and Uses.- The walking drag line excavator is different from other drag lines in that it is equipped with a a traction device which allows it to walk in any direction. This renders the machine very portable which is a point of considerable advantage for the machine can walk from one ditch to another where the ditches are not too widely separated. A walking machine can oftentimes be erected at a railroad station and walked to the point of beginning work thus saving time, expense, and trouble in hauling the parts and assembling the machine at the site of the work. A rate of about 25 or 30 feet per minute is the ordinary pace for this type of machine.


Contract Price
Cost per Cu Yd in Cents
10
8
6
4
2
0
Large Machine
Small Machine
Average to Date
(both machines)
Progressive Average
Cost Chart
Contract No. 7
Bogue Phalia Drain. Dist.
June
July
Aug.
Sept
Oct
Nov.
Dec.
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
1914
1915



Cost per Cu. Yd. in Cents
10
8
6
4
2
0
Contract Price
Large Machine
Small Machine
Average for Period
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
1914
1915
Unit Cost Chart
Contract #7
Bogue Phalia Drain. Dist.

1.Drag Lime

c-Guided Bucket

Description.- The guided boom drag line excavator is unique in that in addition to the regular boom used by other drag line machines, it has a guide boom which works in a fashion similar to the lower section of the boom of the walking dredge. The drag line boom, however, is not straight but curved. In a neutral position, the guide boom extends horizontally from the pivot at

Guided Bucket Drag Line Excavator

the foot of the main boom for about three quarters of its length. It then bends on a sharp radius to the shape of a cune with the upper end vertical and directly under the point of the main boom. The outer end of the guide boom is hung from the main boom by a cable. Along the under side of the guide boom, the drag bucket rides. The main advantage in using the guided bucket is that the bucket is under control and cannot roll over in hard material or ride over hard spots, and can be guided to cut almost any slope desired.

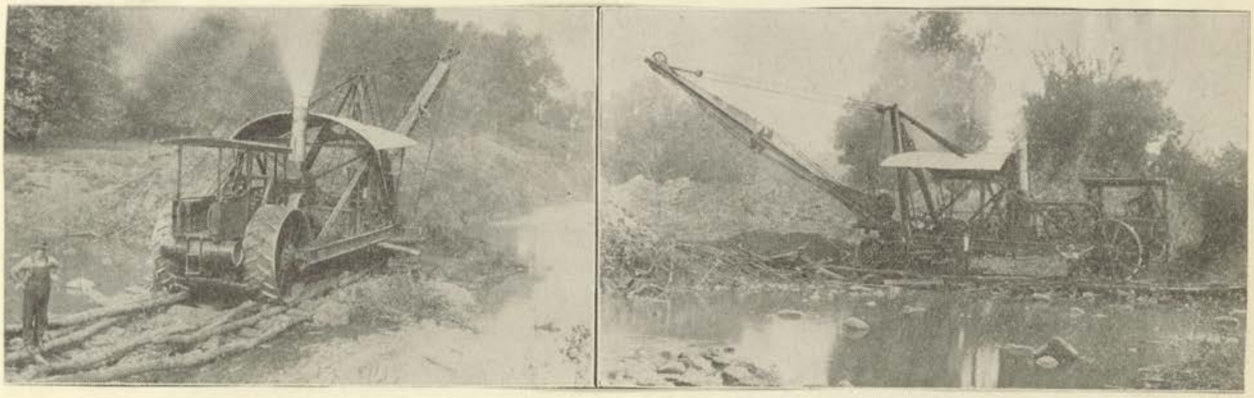
The remaining parts of this type of machine differ but slightly from the ordinary drag line. These machines are made with booms from 25 to 50 feet long and with buckets from 1 1/3 to 2 cubic yards in capacity.

Uses.- The guided boom machine is useful on moderate sized ditches and levees and in cleaning out old ditches. It is also employed in trench work for sewers and tile. With skillful operation, the usual type of drag line bucket can be controlled to an extent so that the difficulties for which the guide boom is a remedy are of little importance. The added motions necessary in operating the guided bucket are scarcely worth while in ordinary work and it seems probable that because of its complexity without the gain of any important advantage, the guided boom drag line machine will never come into extensive use .

1.Drag Line

d-Tractor

Description.- The tractor drag line is a combination of an oil or steam tractor with a drag line frame. In the leading oil tractor type, the front wheels and axle of the tractor are removed and the front end of the tractor is placed on cross members of the deck frame of the drag line machinery. The front end of the deck frame is carried on a heavy axle and two wide tread wheels. Side beams extend back to connect by means of an extension hub bolted to the rear and driving wheels of the tractor. The boom is of latticed steel channel construction and moves around a swinging circle set directly over the front axle. The boom is slung on a multiple part line from an A-frame arrangement attached to the deck. A drag bucket shod with a heavy manganese steel cutting lip and having a serrated cutting edge is used. The bucket capacity is ordinarily 1½ cubic yards. Power is transmitted from the tractor



Two Views Of Oil Tractor Drag Line
Excavator At Work

crank shaft to the ditcher machinery thru a roller link transmission chain. One or two men are sufficient to operate the machine. When wet conditions are encountered, a towing rig is made use of.

The steam traction shovel is slightly different in detail. The digging outfit is coupled to the engine drawbar of a regular undermounted traction engine. Cables extend from the A-frame to the front end of the boiler to act as guys and braces. The digging machinery is placed on a framework of I-beams independent of the traction engine and is mounted on two 36 inch wide tread wheels When moving from place to place, a third wheel is attached so that the digging machinery rests solely on its own wheels at that time and makes travel easier and safer. A steel boom is used about 40 feet long and carrying a bucket holding either $\frac{3}{4}$ or 1 cubic yard.

Uses.- The traction type of drag line may be used for a variety of ditch work and has also been used on levee construction. The machine is designed principally for lateral ditches in large drainage systems made up of moderate sized ditches where the mileage is large in comparison to the yardage involved. The machine is portable and is readily moved from job to job under its own power. A feature of this machine on general work is that the tractor may be disengaged from the digging apparatus and used for hauling or other work.

Performance and Costs.- An oil tractor excavator was employed on the Orton Levee District, Ashdown, Arkansas, in enlarging old levees and making new ones. The machine operated on wheels during dry weather and on skids with the towing rig during the wet season. The average output was about 800 cubic yards per 10 hour shift. The work was done in timber and moderate sized stumps were handled without special difficulty.

At Glidden,Iowa, an oil tractor was successfully used in straightening a river channel. The work required a channel 35 feet wide on the bottom, from 8 to 12 feet deep, and having 1; 1 side slopes. The method of double cutting, that is excavating one half of the ditch and placing the spoil all on one side and the repeating the process by following down the other side of the ditch and throwing all the material on the nearest bank, was used and the work was completed satisfactorily. The contract price for this work was 5¼ and 7 cents per yard.

2. Tower Machines

Description.- The essential features of tower machines or slack line excavators are a main tower of considerable height from which cables extend across the excavation to an anchorage on the opposite side. A drag bucket operates on the cable by means of engines in the main tower. There are two methods for anchoring the outlying end of the cables. One is to attach them to a small but heavy tower; the other is to stretch a cable parallel to the center line of the excavation between dead men and to attach the end of the digging cable to this by means of a moveable clamp. The methods of operation of each of these types of tower excavators will be made clear by describing two installations where these machines were employed . These descriptions will be taken up immediately following the discussion of the uses of tower excavators.

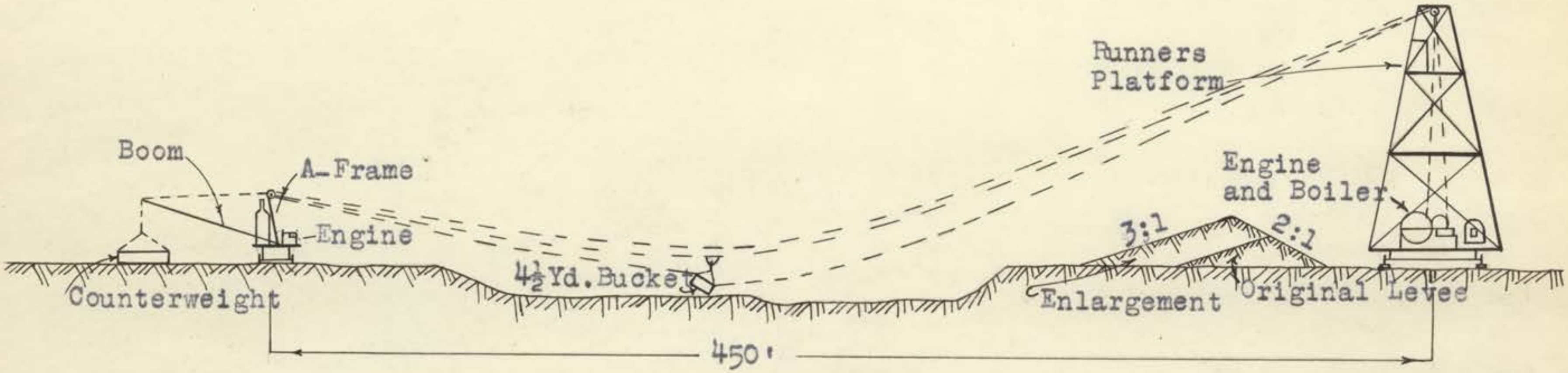
Uses.- The broadest field for the tower excavator lies in levee building where the great reach which the machine possesses makes it particularly valuable in making wide shallow borrow pits. Tower machines are also used for large wide channels .

Two Tower Excavator on Mississippi River Levee Enlargement.- The machine used on this work was known as the Oglevie levee builder and was used in enlarging the levees of the Mississippi River a few miles below Memphis, Tennessee, during 1915.

The essential features of this tower machine are shown on the accompanying sketch. An 80-foot main tower was set up near the land toe of the existing levee. About 450 feet distant, a tail tower was stationed. Both towers moved on tracks made up of heavy section railroad rails. Cables were suspended between the towers. On one cable was a $4\frac{1}{2}$ yard bucket. The remaining cables operated the bucket . Raising or lowering the bucket was accomplished by tightening or slacking the cable from which the bucket was hung.

The main tower was built of very heavy timbers and was mounted on heavy trucks which ran on the rails. The rails were fastened to short ties in sections about 30 feet long. As the rate pf construction was about 100 feet per day, no great trouble was experienced in moving the track. The engines which control the cables were placed on the base of the tower. A locomotive type boiler furnished power. The operation was controlled by a runner from a platform near the top of the tower.

The tail tower is in reality not a tower at all. It was a flat car on a wide gage track from which was erected an A-frame to a height of about 20 feet. The main cables passed thru a sheave at the top of the A-frame. The weight of the cables and the pull on the bucket was counterbalanced by a heavy box partially filled with earth which was hung from a 50 foot boom swung from the A-frame. The counter weight rested on the ground during operation, the cable to the A-frame being kept taut, however. When a move was made, the box was lifted by an engine on the car until it swung on the boom clear of the ground. The tail tower was moved by winding up a cable attached to a dead man buried ahead of the tower.



LAYOUT SKETCH

OGLEVIE TOWER
LEVEE MACHINE

The bucket used was of heavy steel construction rated at $4\frac{1}{2}$ cubic yards capacity. In good digging, the bucket carried from 5 to $8\frac{1}{2}$ yards but in sticky gumbo material, considerable difficulty was encountered in obtaining a full load. The speed of operation was about 2 trips of the bucket in 5 minutes. Delays in addition increased the average time per bucket.

In digging, the bucket was lowered in the desired place, the cables tightened to fill the bucket, which then was pulled along the surface to the toe of the levee. The rear of the bucket was then elevated so the the teeth and front edge of the bucket would drag over the levee slope as the bucket was pulled to the top of the levee. This procedure was followed in order to compact the new fill as much as possible. In gumbo soil, the bucket did not scour well and it was necessary to stop after every few bucket loads and clean the inside with a hose and water. All large stumps in the borrow pit were removed by blasting ahead of the work. The completed levee was well formed, uniform, even, and smooth in appearance. Part of the appearance was due, however, to two men being used to dress up the slopes.

The best month's run for this machine was 22,000 cubic yards in 28 shifts of 10 hours each. This is equivalent to about 800 yards per day. The contract price for the work was 20 cents. The cost of operation was about half this amount.

Single Tower ExcavatorOperation in Central Mississippi.- The machine used on this work is known as the Field Tower Excavator. The work consisted in excavating a large channel 80 feet wide on the bottom and 17 feet deep with 2:1 slopes and berms 30 feet wide.

The machine was a one-tower excavator, which operated a 2 yard bucket on a gravity cable attached at one end to a drum on the tower and at the other to an anchor line the span length from the tower. The tower was of heavy frame construction mounted on trucks running on railroad rails with a 30 feet gage. The tower was 75 feet high. The gravity cable was joined to the anchor cable by an automatic sliding clamp which held firm during digging but which moved readily at other times. The operation of the machine was controlled from a platform at about a third of the tower height.

The operation were carried on using a span of 375 feet. The bucket averaged about one trip each minute. At intervals of from 25 to 35 minutes the machine was stopped to change position. This operation required from 2 to 6 minutes. The machine was operated for 216 hours during the summer of 1913 and during this time 25,800 cubic yards were excavated. This was at an hourly rate of 117 cubic yards.

The cost of operating was as follows:

	Total Cost	Unit Cost
Labor and Board------------	$1103.75	$0.0430
Coal ----------------------	293.25	.0114
Oil, Repairs, etc----------	463.48	.0132
Depreciation --------------	243.50	.0094
Interest ------------------	58.50	.0022
	$2162 .48	$0.0792

Theitem for labor and board includes field superintendence but no overhead charges are included. These would bring the total unit cost up to 10 or 11 cents per cubic yard.

3. Grapple Dredges

Description.- Grapple dredges are so called because of the fact that they are equipped with long booms from which hangs a grapple bucket which may either be of the clam shell or orange peel type. The machinery is placed either on skidders or is floated on a hull. The widest use of this type of dredge on reclamation work has been in California. The dredges used in that state are many of them built with costly hulls and are seaworthy. The heavy timber of the South has presented difficulties in the way of stumps which the grapple dredges have not surmounted owing to a lack of the enormous power necessary to uproot and remove stumps. Some of the California dredges have booms 230 feet long and carry buckets holding up to 6¼ cubic yards.

Uses.- Grapple dredges may be used for levee building and channel excavation in fairly open country where few stumps will be encountered. Due to the very long booms used, grapple dredges are particularly well fitted to levee building where the material is taken from a stream bed and placed well back on the banks.

Performance and Costs.- A large number of long boom clam shell dredges have been operated in the Sacramento Valley in California. On one of these dredges, the "Armour", careful cost records were kept for a period of two years. The hull of this dredge is 61 feet wide, 140 feet long, and 14 feet deep. The boom is 225 feet long and the bucket has a capacity of 5 cubic yards. The operating cost was $95 per day and repairs amounted to $25 per day. Considering that one day out of six was used for repairing, the daily cost would be $116. The "Armour" placed from 30 to 35 buckets of material per hour. The bucket averaged about 90 per cent of the rated capacity over a long period of time and operating in different materials.

Another dredge used in the Sacramento Valley was the "Trojan", a boat 70 feet by 150 feet with a 200 foot boom and a $6\frac{1}{4}$ yard bucket. While placing material 155 feet from the side of the hull, not counting the time for moving, 48 swings per hour were made during a tested short period of time. The dredge was operating in river sand and the buckets came up level full. On the same class of work, long time records show from 37 to 41 swings per hour, including time for moving forward but not including any time for oiling or repairs.

In constructing a levee at some little distance from the Sacramento River, working in heavy clay, over a distance of 21 miles, a tptal volume of 5,100,000 cubic yards was placed to form a levee with 10 foot crown, slopes of $3\frac{1}{2}$ to 1 and 2 to 1. The greater part of the levee was built to a height of over 25 feet. The material was so hard that over half, about 2,880,000 yards to be specific, was blasted before excavation.The average cost of excavating the material not blasted was 9.13 cents per yard and the average cost of removing the blasted material was 6.58 cents. The blasting cost 2.84 cents per yard so that the total cost for excavating the material that had to be blasted was 9.42 cents per cubic yard. These costs do not include clearing and grubbing.

Another levee was constructed immediately along the river from river sand. This levee had slopes of 3 to 1 and 2 to 1 and averaged 12 feet high. Excluding clearing and grubbing, the cost of excavating 2,300,000 cubic yards of material was 8.36 cents.

C.-REVOLVING WHEEL OR CHAIN MACHINES

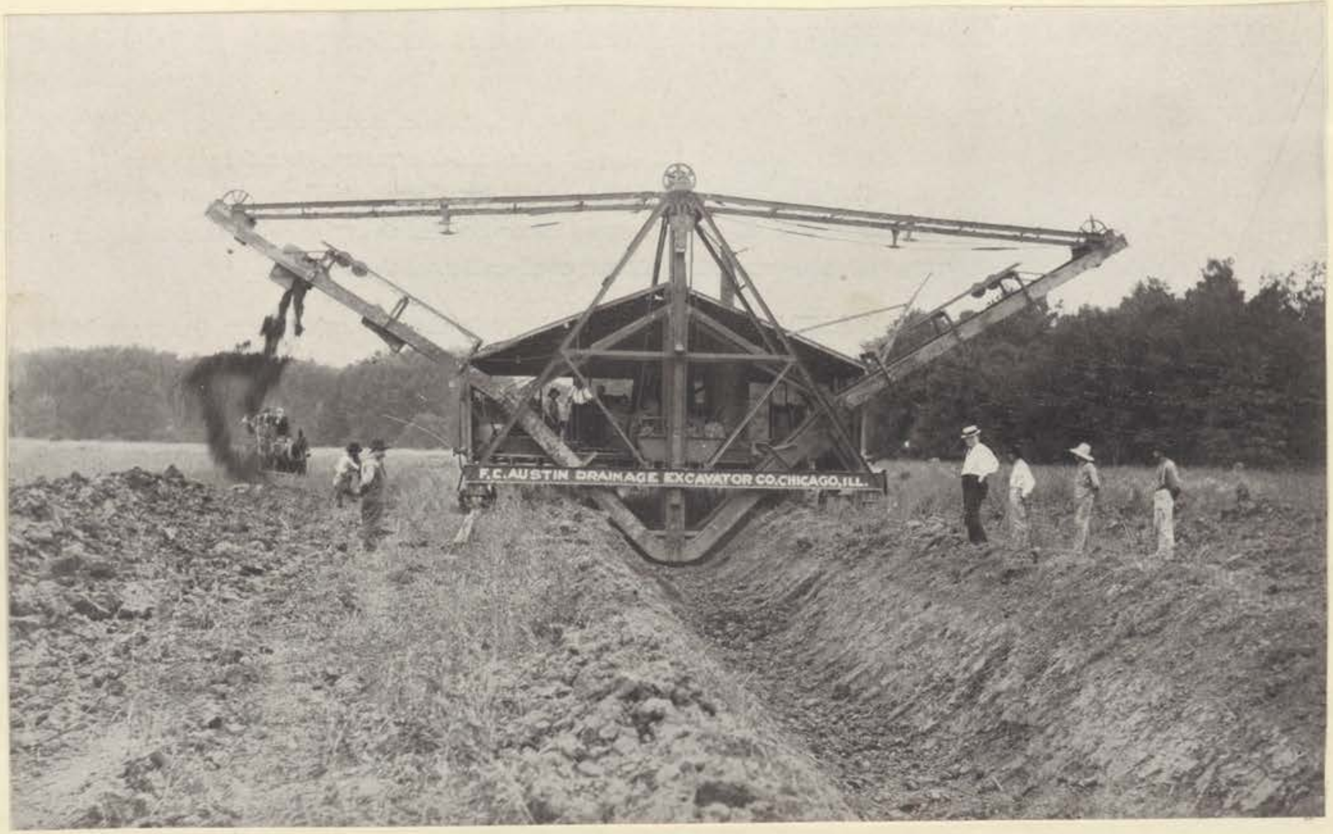
1. Templet Excavators

Description.- This type of excavator consists of a structural steel frame which spans the ditch and propels itself on wheeled trucks or caterpillar traction wheels which run along the sides of the ditch. On the frame is placed the operating machinery and on the front is a large steel bucket guide frame which is , in reality a large templet shaped to the dimensions of the cross section of the ditch. The guide frame moves vertically . Along the outer perimeter of the guide frame, the excavating bucket travels in guideways transversely of the ditch, The bucket shaves off a thin slice down one side and across the bottom and up the opposite side. The guide frame extends above and beyond the limits of the ditch and the bucket carries the material to the outer end and then dumps onto the waste bank. The bucket, after dumping, reverses direction and makes another cut as it travels back across the sides and bottom, dumping on the opposite side of the ditch.

In operation, the guide frame is lowered progressively with the excavation until the ditch has been cut to the required cross section.

Either steam or oil drive is used on templet excavators. The buckets used vary in capacity from ½ to 2 cubic yards. Two men are all that are required to operate the machine.

Uses.- Templet excavators are used to dig ditches from 3 to 30 feet in width and up to 12 feet in depth. The machine is designed to cut a ditch to an exact and smooth cross section, a thing which is not possible with other types of equipment. This



Templet Excavator

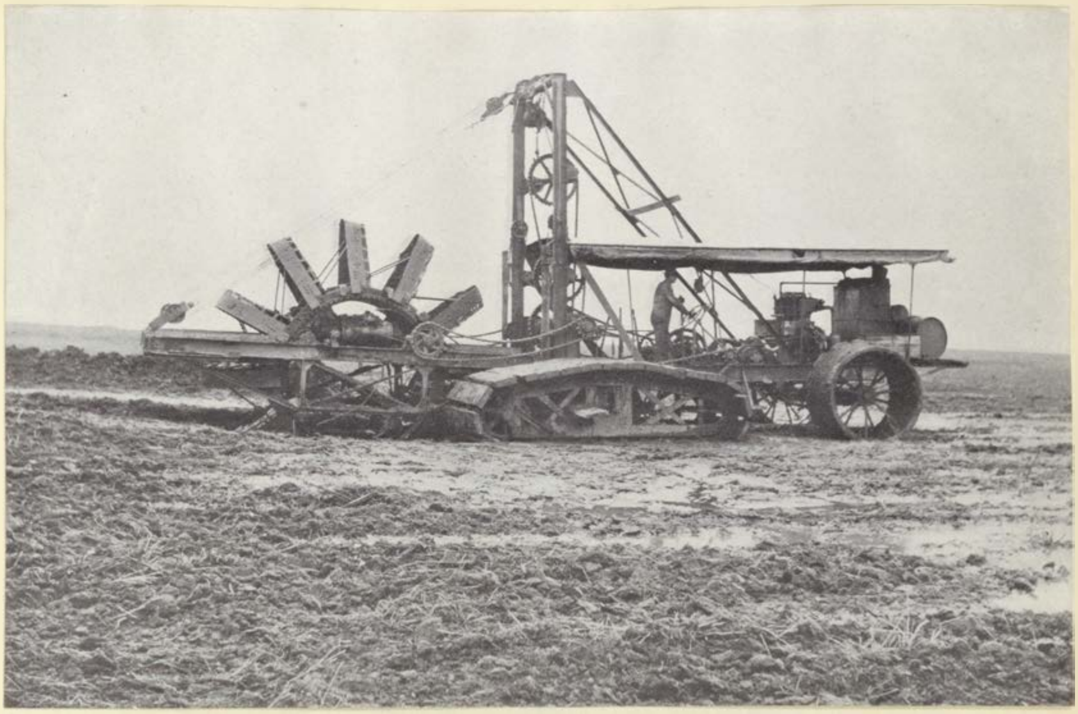
ability is desirable from the standpoint of an efficient waterway, both hydraulically and from a maintenance standpoint. The machine can not be used in ground which is too wet and swampy to permit good tracking and it can not successfully handle stumps and very hard materials. Since it is not well adapted to the swamps, the templet excavator has met with little favor in the South where swamp conditions are very prevalent.

Performance and Costs.- Mr. D.L Yarnell in a bulletin on "Excavating Machinery" describes the construction of about a mile and a half of ditch with a 24 foot bottom width, side slopes of 1 to 1, and depths ranging from $3\frac{1}{2}$ to 7 feet. The work included the excavation of about 43,000 cubic yards of yellow clay soil. An average daily progress of slightly more than 340 cubic yards was achieved. The operating cost was 8.1 cents per cubic yard. Counting in interest and depreciation, the total cost would be about $11\frac{1}{2}$ cents per cubic yard.

2. Wheel Excavators

Description.- The wheel excavator is so named because it excavates by means of a large wheel attached to a pivoted steel frame which works about the rear end of a tractor machine which supplys the power for operation. On the circumference of the wheel are a series of buckets with sharp cutting edges . As the wheel revolves, each bucket slices off a thin layer of material from the ditch. This material is then carried to the top of the wheel where the dirt falls on to a belt conveyor set within the wheel at right angles to the plane of the circumference. The conveyor extends to the side of the ditch and deposits the material there. As the digging progresses, the wheel is lowered continuously until the desired grade is reached.

The traction equipment is usually mounted on large rear apron wheels which support the machine in wet soils. The machine can move over the ground under its own power from ditch to ditch.



Wheel Ditcher Working In Ohio Marsh Land

Uses.- The wheel excavator is particularly adapted to digging small sized ditches up to about 10 or 12 feet in width and 5 or 6 feet in depth. Under certain conditions, where the manufacturers have shown a spirit of cooperation with the owner of the machine in efforts to fit the machine for properly working under a given set of conditions, the wheel machines have given excellent results. The major part of the operations of these machines have been carried on in Florida and Louisiana in marshy soils. In many cases, the original machines installed on the job were not well adapted to traveling over the soft ground by reason of inadequate apron or caterpillar traction wheels . The machines, as a result, mired in the soil and gave much trouble in extricating them . The manufacturers of one make of machine refused to assist the owners in modifying the machines to suit the conditions but the leading makers of wheel excavators studied the problems encountered and increased the bearing area of the traction wheels and changed the details until satisfactory operation was attained.

Wheel machines will not handle large stumps but the cutting wheel will shear off small roots from a main stump and if the stump itself is struck, the engine will stall until the wheel is raised over the stump. Where there is considerable stumpage, it is necessary to blast the stumps ahead of the excavation. In some parts of Louisiana, in regions which were formerly cypress swamps, whole tree trunks are found buried where they have fallen over. Under such conditions, the wheel excavator cannot operate.

Performance and Costs.- A wheel machine made by the Buckeye Company was used recently on a tract of land near Lake Pontchartrain 15 miles from New Orleans. On part of the work, there was a heavy growth of shrubs, some 5 to 10 feet high, from 2 to 3 inches in diameter and having a substantial root system . For the purpose of alignment, a strip 2 to 3 feet wide was cleared thru the shrubs. On this work, the actual cost of operation was about 2 cents per cubic yard.

In 1914, a Buckeye machine was used to cut a ditch $5\frac{1}{2}$ feet deep, 3 feet wide on the bottom, and 12 feet wide on top, in Florida. An average of a quarter of a mile a day was excavated with a maximum of twice that distance. The average volume of earth moved was about 2,000 cubic yards. A large part of the work was done with water from 6 inches to 2 feet over the surface. The soil consisted of from 1 to 5 feet of turfy muck underlaid with a sandy clay or marl subsoil. Interspersed at intervals were ridges of saw palmetto underlaid with a hard brown hardpan. The average operating cost was about $50 per day . This would be equivalent to about $2\frac{1}{2}$ cents per cubic yard of material.

In Dade County,Florida, a Buckeye machine was used to remove 1,300,000 yards of muck and sand from 250 miles of ditches at a cost of 2.7 cents per yard. The ditches averaged 5 feet deep, $2\frac{1}{2}$ feet wide on the bottom, and 9 feet wide on top. The average monthly capacity of this machine was 54,400 cubic yards. Three men were required to operate the machine and four men were employed to cut out a strip 25 feet wide along the ditch line.

3.Trench Excavators

Description.- There are in use today several types of machines designed to excavate narrow trenches in which drain tile or sewer pipe may be laid . These machines are of no use from the broad standpoint of land reclamation which involves the drainage of large tracts of land and does not concern itself with the methods of specialized farm drainage of small units which together make up the large tracts. The discussion of trench excavators will therefor not be taken up in this thesis.

4. Ladder Dredges

Description.- The ladder dredge is a floating excavator. On the front of the hull is a framework called a ladder. One end of the ladder is pivoted to the hull and the outer end is suspended from a gantry frame placed on the front of the hull. Endless chains run around the ladder which carry buckets at short intervals. These buckets hold from 3 to 15 cubic feet. The chains are revolved around the ladder which is lowered into the material to be removed and as the chains revolve the buckets pick up a load from the bottom and front of the material. This is carried to the top of the ladder where it is dumped automatically onto a belt conveyor. The conveyor either takes the material to a scow along side or , by a special arrangement, provides for dumping along the banks.

Use.- Altho the ladder dredge has in the past been used in excavating large canals, it is not ordinarily adapted to general use on such work. The dredge can not work well in small channels and is most efficient in large canals, rivers, and harbors. This type of excavator also has trouble in properly disposing of the excavated spoil from such channels as are dug for drainage purposes. In a word, the ladder dredge is a highly specialized type of equipment which finds little use in drainage canal excavation.

D.-HAND AND TEAM

1. Scrapers

Description.- Scrapers in general consist of some kind of a pan or scoop which may be drawn by horses and filled with earth. The simplest type pf scraper is known as the slip scraper. This is merely a steel scoop holding from 3 to 7 cubic feet to which is attached a heavy bail for hitching the horses to. The scraper has two wooden handles which are used in filling and dumping the scoop. Slip scrapers are economical for moving earth only short distances of 100 or 200 feet.

Wheel scrapers are the next size of scrapers above slips.

Wheel Scrapers At Work

These consist of a steel pan with a rectangular cross section which is mounted on a single pair of wheels. A tongue is attached to which a team of horses is hitched. Wheel scrapers hold from 10 to 17 cubic feet. These scrapers are used economically up to hauls of 800 feet.

The accompanying illustration shows a recently developed four wheel scraper known as the Maney Scraper which has met with success. This scraper carries a 1 yard pan slung from a frame by chains and may be either horse or traction drawn. Maney scrapers may be used for hauling up to distances of 2000 feet.

Uses.- Scrapers are useful in land reclamation chiefly in placing earth in levees altho they are also of value for digging small ditches.

Costs.- Costs for various pieces of work vary with the soil conditions and the length of haul. An average price of from 25 to 30 cents prevailed on drainage and levee work during the pre-war period, that is before 1916 and 1917.

Maney Scraper

2. Graders

Description.- Graders are of two kinds, road or scraping, and elevating. The former consists of a scraper blade hung from from a frame mounted on either two or four wheels. These graders are useful for small ditch work only and will not be considered further.

The elevating grader consists of a plow which throws earth on to an inclined moving belt which in turn carries the earth upward to the outer end of the belt where it either falls into wagons or in a waste pile. The plow and conveyor are mounted on a steel frame on four wheels and a mechanical arrangement of wheels, gears, and chains serves to control the digging.

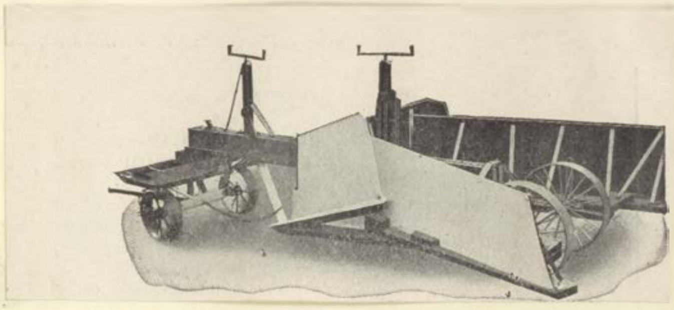
Uses.- Elevating graders are used in loading wagons in levee construction, the wagons depositing the material in the levee.

Performance and Costs.- The manufacturer of a leading make of grader states that, using six teams, one operator, and two drivers, the daily expense would be about $19, estimating teams at $2.00 and drivers at $2.50. In ordinary soil, it is stated that 1000 yards a day can be moved which would be less than 2 cents per yard for operation. Under present conditions, teams would cost $7.00 per day with drivers and estimating the cost of the operator, the daily cost would fall little short of $50. This would make a cost of about 5 cents a yard for the work. In addition, the cost of carting the material must be added to arrive at the total cost of the work.

3. Plows

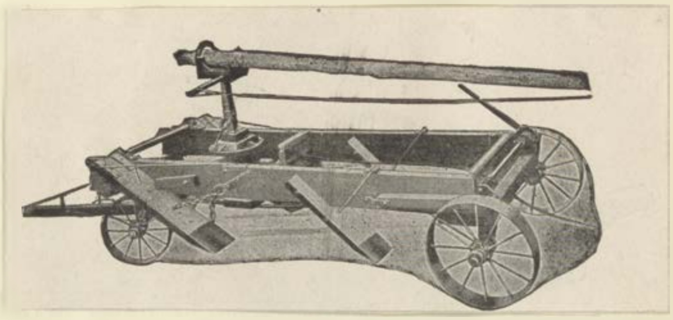
a-Capstan

Description.- Capstan plow ditching rigs consist of one large plow and at least two capstans with from 3000 to 6000 feet of cable. The plow is fitted with mouldboards shaped to form the sides of a shallow ditch and throw the dirt from 3 to 5 feet away from the edge of the ditch. The plow is mounted upon moveable trucks. The capstans consist of a well built frame set on wheels



Capstan Plow

Capstan
(Note mud claws)



for hauling and have two self-setting mud claws to hold them in position. On the frame is a spindle or drum around which the cable is wound in operating the plow. This drum is revolved by a sweep about 24 feet long to which four horses are hitched.

The method of operation is as follows. The plow is lowered to the ground at the place where the ditch is to begin and the trucks used in transporting the plow are removed. The capstans are set from a quarter to a half mile ahead of the plow , one on either side of the line of the ditch to be dug. The capstans may be set on land that is dry and the plow pulled thru low wet places where it is desirable to have ditches. The cable is attached to one capstan and passed thru a sheave on the plow and then brought back to the other capstan. As the drums on the capstans are revolved by the horses on the sweeps, the cable is wound up and the ditcher plow pulled ahead. To operate a capstan plow outfit requires about 16 horses and 6 men, not counting in a cook or camp men where a camp is maintained.

Uses.- The capstan plow ditcher will cut small ditches from 8 inches to 2 feet wide on the bottom, from 4 to 10 feet wide on top, and from 2½ to 5 feet deep. These plows have been used to a large extent in Minnesota, Wisconsin, and northern Iowa. A common name for the plow is a swamp ditcher and it is true that it works better in a wet soil than in dry. Where the material is too soft to hold the shape of the ditch as cut, the plow is not very satisfactory. It works best when water follows in the ditch that is cut as this helps the mouldboard scour. More power is also required in dry earth.

The full sized ditch is not usually obtained the first time over and a second cut is made to make the desired size of ditch. Small stumps and boulders cause much trouble and hinder the work considerably.

Performance.- In open prarie soil, a capstan plow should cut from 150 to 200 rods of ditch per day. Where timber is encountered, the rate is at least cut in half.

Costs.- Contract prices for plow ditching with capstan plows has in the past varied from about $1 to $2 per rod.

3. Plows

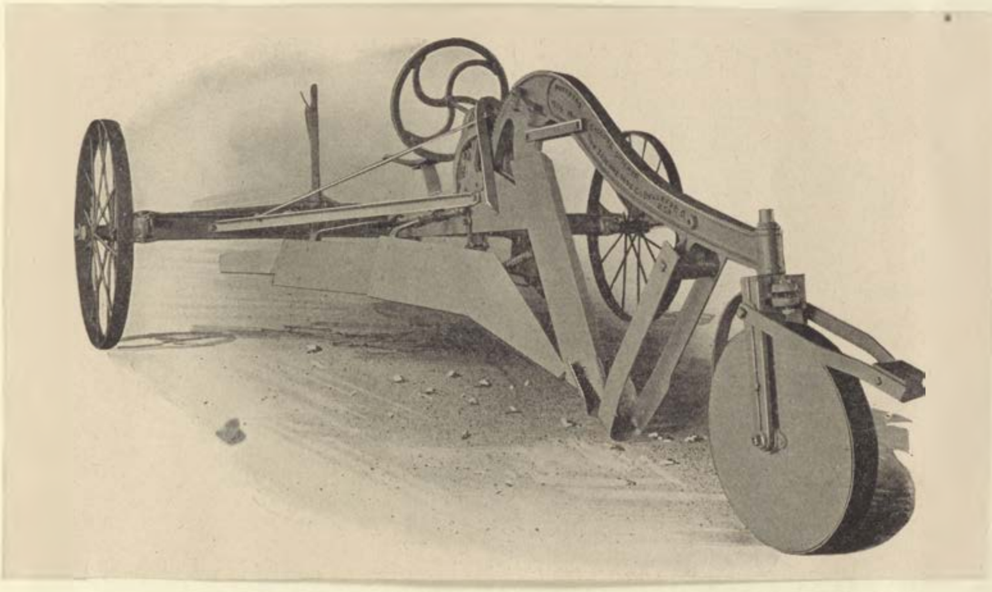
b. Trench Plows

Description.- There are several models of plows for making shallow trenches for tile or for small farm ditches. One of the most successful of these plows is mounted on two rear wheels having a spread of 11 feet and with a solid wheel a few feet ahead of the point of the plow which is hung on an iron frame between the front and back wheels. At the front of the plow, six horses are hitched abreast to a 14 foot evener, three horses traveling on each side of the ditch line. Sometimes tractors are employed instead of horses to furnish the motive power.

In addition to the six horses, three men are required to operate the plow, two acting as drivers and the third riding and operating the machine. The operator regulates the depth of cut by a steering wheel acting thru a worm gear. Not having to pay any attention to the driving, the operator is free to concentrate his whole thots to the cutting of the ditch and in this way he is able to make a smooth cut which will require little if any trimming if tile are to be laid in the trench. The machine does not cut the full depth in one time but requires from 4 to 8 times over the ditch to cut to the full depth.

As the dirt is plowed out of the ditch,the moldboards assist in depositing it on both sides of the ditch.

Uses.- The principal field for this type of excavator is in making tile trenches but it is also useful in digging small farm ditches. A ditch 16 inches wide and 3 feet deep is about the maximum that can be dug. The machine will operate successfully in



Trench Plow Ditcher

any soil that is solid enough to afford a footing for the horses. In rocky soils where boulders are met with, these interfere with the operation insofar as it is necessary to stop the plow and raise the points to pass over the obstruction. The boulder must then be removed by hand. Stumps and roots also offer insurmountable difficulties to this type of ditcher.

In using this machine for making tile trenches, it is usually necessary to dress up the bottom to an even grade with a tile scoop and remove the particles of dirt that roll back into the ditch.

Performance.- The capacity of plows of the trench type varies according to the heaviness of the soil in which operations are carried on. Working under favorable conditions as much earth can be removed by a plow in a day as 25 or 30 men can throw out with shovels. The manufacturers guarantee that 300 rods of ditch can be made in a day cutting to a depth of 2 feet. This rate is based on using 6 horses but if more are used, a deeper cut can be taken each time thru and a greater rate can be attained.

Costs.- The cost per rod can be found by estimating the cost of three teams and three men to operate the outfit. Under present prices, the teams would cost at least $7 each or $21 in all and the men would average $3 each or $9 in all. The total operating cost per day would then be about $30. For 300 rods, the cost per rod would be about 10 cents. Where farmers use their own teams and do the work themselves, this figure may be reduced somewhat.

4. Shovels

Description.- A discussion of the means available for excavation of ditches would be incomplete witout a passing mention of digging the earth out by means of hand shovels. In the case of small isolated ditches on the farm or in making tile trenches it is frequently not economical to install a machine to do the work and in such cases, the excavation is performed by hand with shovels. Recent experiments in industrial fields have led to the conclusion that a man can do the most work when he is using a shovel that will hold about 21 pounds of material.

Costs and performance in excavation by hand with shovels varies so much that no general statements can be given that will convey a correct impression of the cost of doing work by this means. For this reason, these topics will not be taken up.

The uses of shovels is ordinarily confined to the excavation of small volumes of earth for if a very great quantity is to be moved, some other means of moving the material will ordinarily prove cheaper.

E.-HYDRAULIC MACHINES

1. Suction Dredge

Description.- Hydraulic suction dredges are substantially constructed boats built to navigate in rivers and harbors. On the front of the hull is a ladder device which lowers to the bottom of the channel when excavation is being carried forward. Thru openings in the end of the ladder, the material being excavated is drawn into the hollow center of the ladder by means of a suction created by a centrifugal pump placed on the deck of the boat. The material thus drawn into the intake pipe, passes thru the pump and is forced thru a discharge pipe to a ball and socket connection on the stern of the boat at about water level. To this connection is

Hydraulic Dredge Of Cutter Head Type

Note cutter head at end of ladder raised. Also note discharge pipe on side of boat.

fitted a line of steel pipe which float on pontoons in the water behind the dredge. The excavated material then is forced thru this line of floating pipe and discharged.

There are two chief types of hydraulic suction dredges. One has a ladder and suction head and merely pushes against a bank of earth or other material and draws it into the intake. The second has a revolving cutter head which has the power to chop up and loosen the material which otherwise could not be pumped. Accompanying this discussion are a number of photographs which show the most important detail features of both tpyes of dredges.

Uses.- The hydraulic dredge is not a type of equipment which can ever come into large use on drainage and reclamation work. The principal field for this dredge is in rivers and harbors where the material to be removed is, for the most part, of a sandy or silty nature which intermingles well with water and hence can be easily pumped. In materials of this sort, the hydraulic dredge works most efficiently and at a low cost. For handling stiff materials such as clay, the cutter head type can be employed to a limited extent. Even with the cutter head machine, clay is not an ideal material to excavate.

The United States government employs many hydraulic dredges in maintaining river channels. The method of operation in this kind of work,which consists largely of dredging bars of a sandy nature and ordinarily recent formation, is to pump the material excavated from the bar thru a long discharge line and discharge it into a deep place in the channel.

Hydraulic dredges have been used under certain conditions to bulid levees. When so used, it is necessary to either build dry earth toes to confine the material deposited by the dredge and prevent its spreading over a very wide base or to use slope boards for forming the slopes. There are some advantages in hydraulic fill levees where such can be built for the material in the levee can be built to flat slopes if desired and the composition of the levee is compact and solid.

Hydraulic Dredge At Work

Note discharge pipe carried on floating pontoons.

As previously explained, the hydraulic dredge of the cutter head type may be utilized for excavating clay material . During the summer of 1917, a dredge of this kind was used in central Mississippi in redredging a large channel in the Bogue Phalia

Front View Of Suction Dredge Showing Ladder Raised
Note suction openings.

Stern Of Suction Dredge Showing Connection To Floating Line

Drainage District. This particular channel had been excavated by a large floating dipper dredge and some time after the work had been completed, the great weight of the spoil banks caused the earth to settle and slide into the channel greatly reducing the waterway. The dipper dredge which had performed the excavation in the first place was no longer on the work and for this reason a hydraulic dredge which was then operating in a nearby river was employed to do the work. Considerable difficulty was experienced from buried logs and stumps and from the cutter head clogging up due to the nature of the material. These facts all contributed to a high cost for the work, but under the existing conditions, the cost was less than it would have been had other machinery been used which would have had to have been moved to the work and installed upon it. The excavated material in this case was disposed of by running the discharge pipe some distance in on the shore.

Performance.- A hydraulic dredge working under favorable conditions in clay soil will remove from 150,000 to 250,000 cubic yards per month. The dredge referred to above on the redredging of the Bogue Phalia channel, working under adverse conditions, averaged about 1050 cubic yards of material per day for 111 days. This boat had a 16 inch discharge pipe. A dredge with a 14 inch discharge pipe working on levee construction near Burlington, Iowa, placed 2,700 yards of material per day of two 11 hour shifts.

Costs.-The cost of dredging by hydraulic dredges is low for work in rivers and harbors, ranging as low as 3 cents on some classes of this work. On drainage channel work , the costs will run considerably higher. For favorable conditions, such costs may

Cutter Head Clogged With Stiff Material

Hydraulic dredge working in Bogue Phalia
Drainage District, Mississippi.

End Of Floating Discharge Pipe From
Suction Dredge

Note deflector for distributing material.

not exceed 10 cents per yard. On the Bogue Phalia work, which has been discussed above, the operating cost alone was 27 cents. This work was not done under contract but had it been so, the cost of doing the excavation would no doubt have been considerably increased.

F.- MISCELLANEOUS

1. Dynamite.

Description, Uses, and Costs.- Dynamite ditching has been the subject of no little experimenting in recent years and while the use of dynamite has not proven particularly reliable and economical, it is nevertheless useful for making small ditches and for cleaning out bars and slides in existing ditches. During summer when the ground is dry, conditions are adverse to successful dynamiting and the results secured will not be as good as when the ground is wet. Gumbo and buckshot soils do not shoot well when dry but fairly good results are secured when wet. In mucky soils which are soft and spongy, dynamite does not take hold of the material due to its spongy character and the charges are largely wasted.

A great deal of the success of dynamiting depends upon the spacing and depth of the charges as well as the amount of the charge. Both 40 per cent and 60 per cent powder is used for blasting ditches. The 40 per cent powder has sufficient power to throw out the earth but is not so sensitive to detonation by concussion or synthetic discharge as the 60 per cent. However, where a battery is used the 40 per cent dynamite will usually give results as satisfactory as the 60 per cent.

For small ditches, one stick of dynamite placed every 18 inches will ordinarily give good results. For large ditches , the spacing should be increased to 2 feet and three sticks placed in each hole. The charges should not be placed too deep as this tends to cause the dynamite to exert its force downward and leaves an unclean ditch. For a ditch 5 feet deep, the charges should be placed about 3 feet deep. These distances and depths should not be considered as absolute but should be used as a guide in starting a new piece of work. A little experimenting with distances and depths and charges will then determine what distances should be used .

Dynamite was used in digging a ditch in heavy buckshot soil near Clarksdale, Mississippi, in 1914 at a cost of about 14 cents per cubic yard. The ditch was a mile long thru a slough grown up in cane and small bushes and for four or five inches the ground was a mass of roots. The soil was thoroly saturated with water. The ditch averaged three and a half feet deep and good results were secured in removing the mass of roots. The cost was no doubt cheaper than if the work had been done by hand for the cost of removing the roots would have been quite an item in the total. On this ditch, one and a half sticks of 60 per cent dynamite were used spaced every 12 inches. From 100 to 200 feet of charges were placed and the whole line set off from one cap by concussion. Two men could blast 400 or 500 yards per day on this work.

One of the largest jobs upon which dynamite has been used for excavating a channel was in the Homochitto swamp near Natchez, Mississippi. Four miles of ditch were dug which averaged 8 feet on top, 6 feet on the bottom, and 5 feet deep. About 27,000 yards of buckshot and blue gumbo were removed. Two miles of the work were under 2 feet of water and the remainder was in saturated soil among stumps and cypress knees. A 60 per cent dynamite was used. The charges were placed in holes spaced in one straight line 30 inches apart and 2½ feet deep. Three sticks or a pound and a half of dynamite was placed in each hole. Where the work was under water, the charges were exploded by concussion, 40 to 50 being set off at one time. On the part not under water, a battery was used. The cost of constructing this ditch was 11¼ cents per yard. In order to deliver the dynamite and blasting accessories on the job, these had to be carried on the shoulders of men for an average distance of two miles thru water two feet deep. In addition, the material had first to be hauled 20 miles to reach the nearest point that teams could approach the work. It would seem, therefore, that under more favorable conditions, the work could have been done cheaper.

It must be borne in mind in noting the above costs, that these are for work done before the European War and that with the price of dynamite three times the cost that it formerly was, and still mounting higher, the cost of dynamite ditching would today be quite different.

8.

MAINTENANCE

Necessity For Maintenance Of Drainage Channels.- If a drainage system is to give the greatest returns upon the capital expended for construction, then it is paramount that the channels be maintained in a free and unobstructed condition so that the capacities for discharging water will be as great as those for which the channels are designed. The regimen of the ordinary drainage channel is that soon after it is excavated, willows, cottonwoods, and other sprouts spring up along the berms and waste banks and in the channel itself. Before the banks of the channel have stood for a sufficient time to weather down to their natural slopes, the earth slides, caves, or is washed into the channel. To some extent, the growth on the berms and waste banks helps to prevent washing and sliding of material into the channel. But the growth in the channel itself is extremely undesirable as an adjunct to an efficient water-way. Unless this growth is removed from the channel section, the capacity of the channel will be greatly reduced. It is therefore a necessity to maintain the channels free from growth and obstructions so that they will properly perform the functions for which they have been designed.

Methods.- In carrying out maintenance work, not only should growth be removed but all debris such as logs, drift, fences, objectional flood gates, and other obstructions should be removed. In removing growth, all that is not too large in diameter should be pulled, roots and all. Growth of such size that it cannot be readily pulled should be cut off at the roots below the surface of the ground with a mattock, an axe, or a machete. In either case, no stub should be allowed to remain projecting above the ground. There will always be some few rootlets left in the ground even after the sprouts are pulled but experience shows that the succeeding season's growth is less from these rootlets than where a stub is allowed to protrude above the surface.

The proper time to pull growth is while the sap is up for if the sprouts are pulled when the sap is down, the pieces of roots broken off below the surface spring up much more readily the next season. The sap is up in the South from about the first of May until the early part of September. The month of August has proven to be the best time for removing growth.

Costs.- The cost of clearing growth from drainage channels varies greatly depending on the number of growing seasons passed thru, the size of the channel, and also upon the location. In 1915, about 40 miles of drainage ditches which had passed thru from two to three growing seasons were cleared of growth and debris under contract at prices ranging from $27.50 to $57.00 per mile. Over half of the work was done at $50 a mile. Practically all of this work consisted of ditches with 14 feet bottom widths, bank slopes of ½ : 1, and depths averaging 8 feet. In 1916, the same drainage district contracted for 95 miles of channel clearing . About 72 miles was done for $35 a mile, 20 miles at $40, and 3 miles at $45. In 1917, the district did its own maintenance work and ditches were cleared which had passed thru from 1 to 5 growing seasons. The prices varied from as low as $12 and $15 for small 14 feet bottom ditches to as high as $175 per mile for the larger ditches which had passed thru four or five seasons growing. The costs given are for Drainage District Number Nine, Mississippi County, Arkansas.

9.

CONCLUSION

The Main Steps in Land Reclamation.- In concluding this thesis, the author desires to point out that the fundamental purpose underlying the entire thesis has been to set forth the seven main steps attendant to the inception and development of projects for the reclamation of overflowed lands. To the discussion of these seven steps, the foregoing pages have been devoted . First, it was set forth that before a reclamation project can progress beyond an initial stage, the economic benefits to be derived from the carrying out of the work must be definitely and clearly established. The importance of strict attention to and careful guidance of the legal affairs of a drainage organization was next pointed out. The necessity for competent engineering in order to assure an efficient and economical drainage system was shown.

Following this, was the methods for making assessments on the basis of benefits to be received. Then the financing of a drainage scheme by issuing bonds was explained.

The greater part of the thesis was occupied with the discussion of excavating machinery. As explained in the introduction, the reason for this is not because of any relatively greater importance, but because that portion of the main subject was first taken up and offered so wide a field that by the time the section on excavating machinery was written, there was not an equal portion of either space or time remaining for treating the other divisions of the subject. However, at the risk of criticism due to this unbalanced condition, the author decided to include all of the portions into which the main subject had originally been divided in order to accomplish as far as possible the chief purpose of the thesis to set forth and discuss the seven steps into which the history of a reclamation project falls.

In discussing excavating equipment, six classifications as to general type of machine were adopted. These six were then sub-divided to differentiate between excavators of the same general characteristics but differing in details.

Lastly, the necessity for adequate maintenance of a drainage system was shown to be a matter of vital importance.

Into some one of the seven steps of progress that have been related, practically every happening in the life of a drainage reclamation development may be placed.